PHYSICS

FOR MIDDLE SCHOOLS

TEXT 2

Experimental Edition

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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PREFACE

The Education Commission while discussing the structure of education in our schools and colleges recommended that teaching of science should commence at class V with Physics and Biology as separate disciplines. It was also suggested that teaching of Chemistry should commence a year later. In response to this recommendation, the Chairman, University Grants Commission, New Delhi, appealed to men of science in universities to get together to prepare curricular material for the middle school with a view to improving teaching of Physics in schools. The response to this appeal was immediate and enthusiastic. Four study groups were constituted, each comprising research scientists, university professors and school teachers, to develop curricular materials. The present book is second in the series.

The Physics Study Group, after long deliberations, considered it necessary to initiate a new approach to the study of Physics at the school level. This approach is essentially based on the active participation of students in the learning process through experimentation, supplemented by demonstration by teachers and discussion leading to the understanding of the basic concepts in Physics. The efforts of the Group have been to relate, as far as possible, the teaching of Physics to what a student sees and does in everyday life. In addition, it is intended to transmit, in some measure, the thrill and excitement of doing experiments which would help students to understand Physics and find something new for themselves. Thus the main emphasis is on the process of science rather than on the product of science.

In order to enable the students to perform experiments, the Group has developed simple and inexpensive kits which form an integral part of the instruction material. Experiments to be demonstrated by the teachers have also been indicated.

The directors and members of the Study Groups are conscious of the shortcomings and limitations of the material. The practical difficulties in implementing the course will become clear after full-scale trial. Teachers in both urban and rural schools are our primary concern and we look forward to a meaningful appraisal of the material. We also look forward to the reaction of the young students to whom it is addressed. We look up to the senior physicists in universities and other institutions for their mature criticism of the material presented here from the standpoint of the contents as well as of the way of presentation. For these reasons, the present edition is being brought out as an experimental edition which will undergo revision after the feedback from various sources.

All my colleagues join me in offering our grateful thanks to Professor D. S. Kothari, Chairman, University Grants Commission, who conceived this idea, for guidance and stimulation; Shri L. S. Chandrakant, Joint Educational Adviser, Ministry of Education; Dr. S. V. C. Aiya, Director, NCERT; Dr. M. C. Pant, Head of the Department of Science Education; Shri Rajendra Prasad; Shri G. S. Baderia, Mrs. N. Mitra and Shri K. J. Khurana in the NCERT who helped in this endeavour in many ways.

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1 MEASUREMENT OF SMALL DISTANCES

1.1 Introduction

You already know how to use a metre scale to measure lengths. You can use a metre scale to measure the length of a pencil, a postcard, a note-book, a piece of cloth, etc. You can also measure the length and breadth of a room with its help. However, it is not always convenient to use a metre scale to measure every and any length. For example, it is not possible to measure the thickness of a piece of paper or the diameter of a pin or a sewing needle with a metre scale. Again, it is not convenient to use a metre scale to measure the distance between say, Bombay and Delhi or the height of a tall tree or a mountain or the width of a river. In this chapter you will learn some simple methods and uses of a few common instruments for the measurement of small distances.

1.2 Measurement of Small Lengths : Method of Averages using a Metre Scale

Take a metre scale. Place it on the table. Try to measure the diameter of a pin with its help. Place the pin along the marks of the scale (see figure 1.1). You will notice that the diameter of the pin is less than the least count of the scale, that is, the smallest division of the scale. This is why you cannot directly

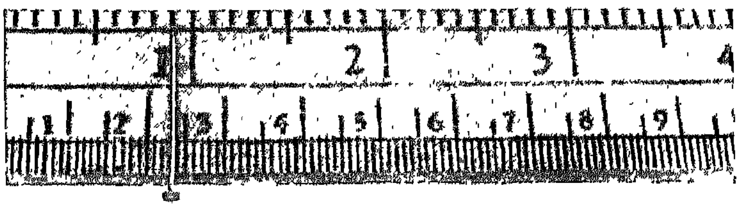


Fig. 1.1

measure the diameter of the pin. If you can procure a large number of similar pins you can perhaps find a solution. See how this can be done.

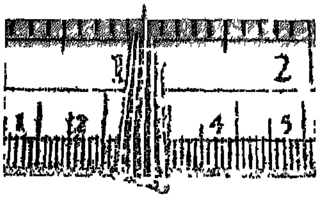


Fig. 1.2

Use the same metre scale and arrange a number of pins side by side without leaving any space between them. Look at figures 1.2 and 1.3. You will notice that the correct way of placing the pins is as shown in figure 1.3. Find the distance on the scale covered by the pins. Do you find any difficulty in keeping these pins on the scale ? Think of various ways of doing it.*

If you now divide this distance by the number of pins arranged in the stack, can you find the average diameter of one pin ? This is why this method is known as the *method of average*. Repeat the above experiment by taking 10, 15, 20, 30 pins and enter your observations in the following table.

Fig. 1.3

Number of observations	No. of pins	Length covered by pins, in cm	Diameter of a pin in cm	Mean diameter in cm

*One of the simple methods is to glue the pins on a strip of transparent paper and then place the strip on a metre scale.

Activity

(1) Find the diameter of a thin wire by the method of average using a metre scale (Hint : Wind the wire on your scale to cover a length of 1 cm on it without leaving any space between the strands. Count the total number of turns within 1 cm and calculate the diameter of the wire.) What happens if the strands are widely spaced or they overlap ?

(2) Cut the piece of the wire into 50 bits and measure the diameter of the wire following the method you used for the pins and compare your result with that of the activity (1) above.

(3) Find the thickness of a sheet of paper of your note-book (exclude the cover).

(4) Can you determine the thickness of your hair ?

(5) Suppose you have only one pin or a small bit of a wire or a thin paper, can you still use a metre scale to measure the diameters or thicknesses ?

Although you can measure small lengths such as the diameter of a pin or of a wire by the method of average, this is not a very convenient and good method. It is not always possible to have large numbers of the same object. Moreover these objects may not always be exactly similar in all respects. Therefore, it is essential that you should have an easy method to measure small lengths such as the diameter of a wire. See if you can think of any simple idea for making a good instrument.

1.3 Screw

Take a screw-bolt and examine it carefully. What do you find ? You find that there are a number of threads on it. Now count the number of threads, say 10, and measure the length of the screw covered by these 10 threads with the help of a scale. From this find the distance between two successive threads. Can you use this distance between successive threads of a screw as a measure of small length ? Examine various screws. Count the number of threads and measure the corresponding length in each case* as shown in figure 1.4. Record your observations as under :

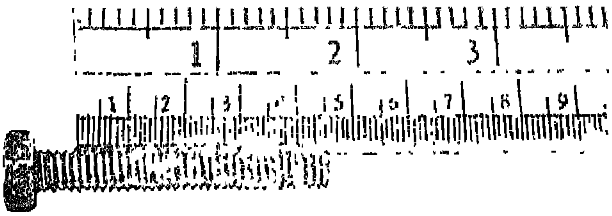


Fig. 1.4

Number of observations	No. of threads in a screw	Length of the screw in cm	Distance between successive threads in cm

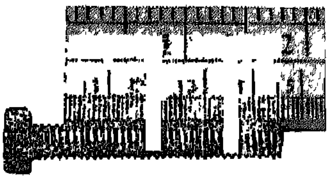


Fig. 1.5

*An easy method to measure on a scale the distance between the 1st and the 10th thread is to use two pins or two pieces of paper as shown in figure 1.5.

How will you verify that the distance between the threads you measured is the correct distance ? Can you think of any other method ?

Take a screw and a nut. Fix the nut on a hard board fixed to a stand as shown in figure 1.6. Fix a scale by the side of the nut so that the movement of the screw can be read on the scale. Fix a small wire or a pointer on the head of the screw as shown in that figure. Turn the screw clockwise ten times. What do you observe ? Has the position of the wire on the scale changed ? If it was reading say 2.0 cm, before you started to turn it what does it read now ? From these observations you will see that as the screw is turned, it moves forward. Can you make it move backwards ? Turn the screw anticlockwise ten times. Note down the distance through which the screw has moved back. Is the distance covered by the backward movement the same as that covered during the forward movement ?

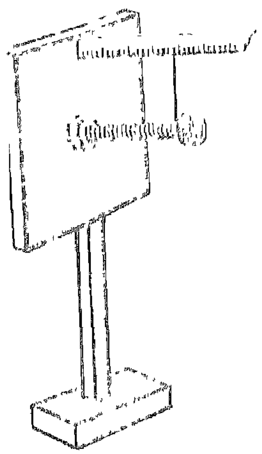


Fig. 1.6

You have determined the distance by which the screw-head moves for ten complete turns. Can you find out the distance moved for one complete revolution ? In finding this distance, do you have to assume anything ? If so what is that assumption ?

Compare the two measurements— (a) the movement of the screw-head when it is turned 10 times and (b) the length covered by 10 threads as measured by the scale earlier. Do these measurements agree ? You can see that the distance by which the screw-head moves when it is turned through one complete revolution is equal to the distance between two consecutive threads. This distance is called the *pitch of the screw*. Pitch of the screw, therefore, is the distance between two consecutive threads or is the distance by which the screw-head moves when it is turned once.

Questions

(1) Measure the pitch of the screw for every screw supplied to you in your kit. Do you find any difference in their values ?

(2) Can you use these screws to measure small lengths ?

(3) Can you measure distances even smaller than the pitch of the screw ?

(4) Fix one disc on the head of the screw as shown in figure 1.7. Can you measure the distance travelled by the screw when it is rotated through one half or one quarter of a turn ?

(5) In case the disc is graduated to have 100 equal divisions, along its circumference, can you measure the distance moved by the screw when it is turned through one small division on the disc ?

(6) If the pitch of the screw is 1 mm and the number of graduations on the disc are 100, what will be the distance covered when the screw is turned through 1 division on the disc ? What is the smallest distance you can measure with this arrangement ?

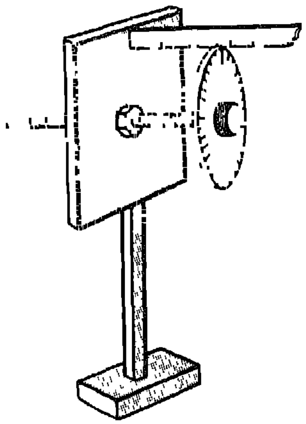


Fig. 1.7

Activity

Take bolt-screws and nuts of different dimensions. Arrange them and find out the correct pairs of screw and nut. Determine the pitch of the screw in each case. You are given a disc whose circumference is divided into 100 equal divisions. Thus you have a circular scale. Fix this disc in turn to each of the screws. Determine the distance travelled by each of the screw when it is rotated through one division of the circular scale. Record your observations as shown in the next table :

Sample	No. of observations	No of rotations of the disc	Distance travelled by the screw	Pitch = distance travelled/ no. of rotations of the disc	No of divisions on circular scale	Distance moved by the screw when it is turned through one division on the circular scale
I						
II						
III						

From the above observations, which of the screws will you choose to measure distances of the order of 0.1 mm ?

(1) What is the smallest distance you can measure with each of the screws ?

(2) What will happen if you fix your disc loose so that it slips while the screw is rotated?

Now devise a method for measuring small thickness using a screw. Take two wooden planks ABCD and EFGH. Fix them parallel to each other on another plank of the same size as shown in figure 1.8 with supporting bars at the top, such as CE and DF. The planks should be rectangular bars of sides 1.5 cm. and of thickness 1.5 cm.

At the centre of the plank EFGH bore a hole and fix a nut so that a screw can be made to pass through it and the plank. To the plank EFGH, fix a small

scale XY graduated in millimetres as shown in figure 1.8. A circular disc, the circumference of which is divided into 100 equal divisions is fixed to the head of the screw as shown in that figure. Turn the screw

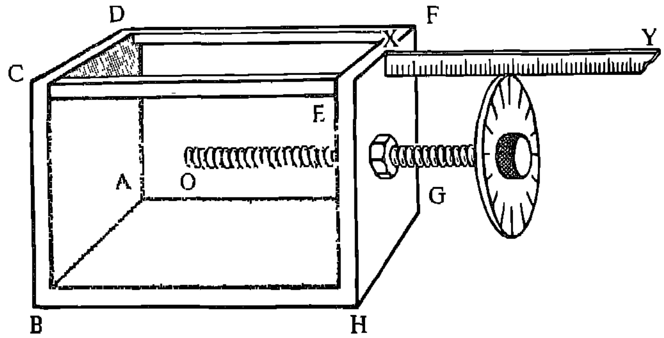


Fig 1.8

through 10 complete revolutions. Find out the length travelled by the screw-head along the axis. Noting the number of divisions on the disc, you can determine the length travelled by the screw-head when it is turned through one division on the disc. Turn the screw till the tip of the screw O just touches the plank ABCD. Take the reading on the scale XY. Turn the screw anticlockwise through 10 revolutions. Can you now tell what is the distance between the tip of the screw and the plank ABCD ? Instead of turning the screw through 10 revolutions if you were to turn it through one rotation, then what would be the distance between the tip and the plank ABCD ? Extend this argument further. If you touch the plate ABCD with the tip of the screw and then turn the screw anticlockwise through one small division on the disc, what will be the separation between the tip O and the plank ABCD ? This is the smallest distance you can measure and is called the *least count* of the instrument. If you are given a glass plate, how can you measure the thickness of the glass plate with this

instrument ? Hold the plate between the tip O and the plank ABCD. Note down the reading on the scale XY and the division on the circular scale in front of the straight scale XY. Remove the glass plate. Now slowly turn the screw so that the tip O just touches the plate ABCD. Note down the complete revolutions and the number of divisions turned on the circular scale. From these observations, can you get the thickness of the glass plate ?

In one typical experiment the pitch of the screw was 1 mm. The circular scale with 100 divisions had to be turned through 2 complete revolutions and 70 divisions on the circular scale so that after removal of the glass plate the tip O touched the plank ABCD again. Can you tell what was the thickness of the glass plate ?

Questions

(*a*) *Instead of wooden planks ABCD, would you prefer thick metal sheets ? If so, why ?*

(*b*) *Is it necessary that the planks ABCD and EFGH should be rigidly fixed to the bottom plank parallel to each other ?*

(*c*) *Would it be better if the U shaped enclosure is made out of the one and the same metal block as shown in figure 1.9 ?*

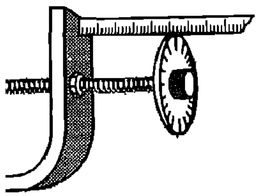
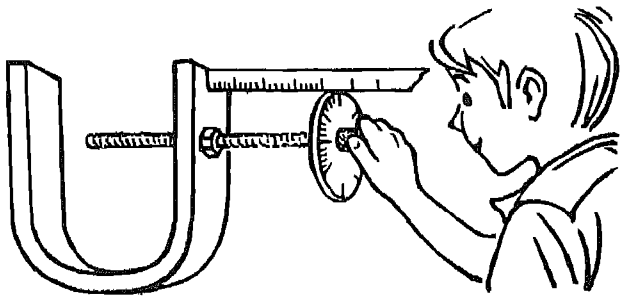


Fig 1.9

The same principle has been utilized in the design of a small instrument called the *micrometer screw gauge* (figure 1.10). This is very widely used by engineers, physicists and machinists.



1.4 Micrometer screw gauge

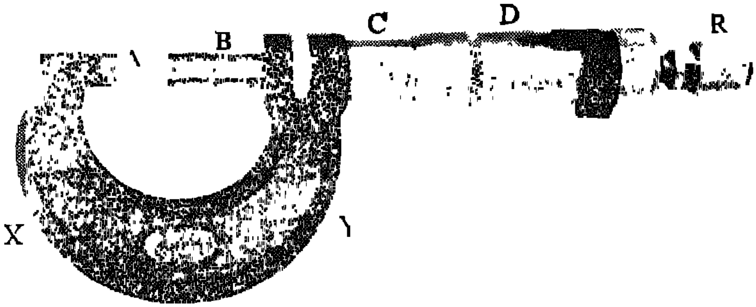


Fig 1.10

XY : U shaped metal piece

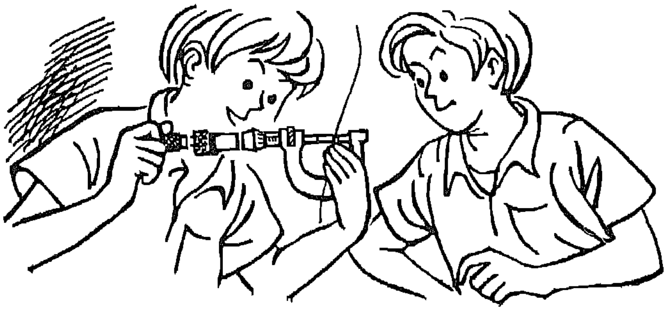
A : Butt end

B : Flat-end screw with equidistant threads cut on it

C : Cylindrical shaft on which a millimetre scale is engraved parallel to the shaft axis.

D Collar-head, which turns together with the screw and is usually divided into 100 equal parts along its circumference and these parts are numbered from 0 to 100. This collar-head serves the purpose of the graduated circular disc

R : A free wheel device called the ratchet head which allows the screw head to turn freely when the pressure on the object held for measurement increases beyond a certain minimum.



Now try to learn how to use a screw gauge for measuring small lengths, say the diameter of a wire.

Take a screw gauge as shown in figure 1.8 and provided in your kit. Turn the screw so that the tip O of the screw touches the plank ABCD. Verify that zero mark on the disc is in line with the linear scale and reads zero on the scale. If they do not, what should you do ?

Take this screw gauge and turn its head so that the screw recedes sufficiently. Insert a wire between the end O and the plank ABCD. Turn the screw till the wire is held gently between the plank and the tip O of the screw. Note the reading on the millimetre scale. Next see which of the marks on the disc coincides with the scale XY. Knowing these two values, can you find out the diameter of the wire ? Is the diameter of the wire equal to the reading on the millimetre scale plus number of divisions on the disc coinciding with the scale XY multiplied by the least count ? Reason out why this is so ?

Question

If the reading on the millimetre scale is 2 and the number of divisions on the disc coinciding with the linear scale is 70, through how many divisions on the circular scale the screw will have to be turned so that the tip O of the screw touches the plank ABCD ?

In one such typical experiment with a wire following observations were recorded :

No of observations	Reading on the millimetre scale	No. of divisions on the disc coinciding with the scale XY	Diameter of the wire
1	1.0 mm	8	1.08 mm
2	1.0 mm	9	1.09 mm
3	1.0 mm	7	1.07 mm
4	1.0 mm	8	1.08 mm

Mean = 1.08 mm

Take care to avoid tightening the screw hard on the object held between the tip O of the screw and the plank ABCD.

Take the reading on a screw gauge by turning the screw only in one direction. This is because due to wear and tear sometimes a slackness occurs in the fit of the screw and the nut. In such a case if you turn the screw in the forward direction and then try to turn it in the opposite direction, the disc has to be turned through few divisions before the screw begins to actually move along the axis. This is called the *backlash.*

Activity

With the help of a screw gauge do the following :

(1) Find the diameter of a pin.

(2) Find the thickness of a page of your note-book, pocket-book, atlas and a post-card.

(3) Find the diameters of knitting needles of different sizes and find a relation between the diameter and the number on the knitting needles.

(4) Find the diameters of sewing needles of different sizes and establish the relation between the diameter and the marking on the needles.

(5) Find the diameter of a small steel ball.

(6) Find the diameters of wires of SWG Nos. 28, 30, 32, 34, 36, 38, 40 and obtain the relationship between the SWG number and the corresponding diameter.

You should enter your observations in your note-book in the following way :

Value of one division on the linear scale =

Distance advanced by the screw when it is turned through 10 complete rotations =

Pitch of the screw =

Number of divisions on circular disc =

Least Count

$$= \frac{\text{Pitch of the screw}}{\text{No. of divisions on the circular disc}} =$$

Verify that when the tip O of the screw touches the plank ABCD, the reading on the millimetre scale is zero and the zero mark on the circular scale coincides with it.

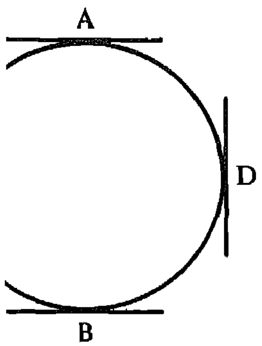


Fig. 1.11

In order to minimise errors in measurement you should take several (at least five) readings and then take the mean. (See table in the next page.)

In determining the diameter of a wire, you should measure the diameter twice at a given section one at right angles to the other, along AB and along CD (see figure 1.11) and at various places (sections). Why should one do this ?

You have seen last year (by drawing circles of various radii and measuring their areas with a graph paper) that the area of a circle is proportional to the square of its radius. If you want to measure the area of cross-section of a thin wire, you should determine its radius accurately. Otherwise a small error in the measurement of radius is magnified in the calculation of the area of cross-section.

Sample	No of observations	Reading on the scale XY	No. of divisions on the circular disc coinciding with the scale XY	Result	Mean
I	1 2 3 4 5				
II	1 2 3 4 5				
III	1 2 3 4 5				
IV	1 2 3 4 5				

Questions

(1) Suppose the pitch of the screw is 1 mm and the number of divisions on the circular disc is 100. What is the minimum distance you can measure with such a screw gauge ?

(2) If in a given screw gauge, the screw advances through 5 mm on turning it through 10 rotations and the circular disc has 100 divisions on it, what

is the minimum distance one can measure with this gauge ?

(3) *It you take a bigger disc and have 1000 divisions on the disc, what is the smallest distance you can now measure ?*

(4) *Suppose you take a bigger and a still bigger disc and have larger number of divisions on the disc, you can reduce the smallest distance you can measure with the screw. Can you go on increasing the number of divisions on the disc indefinitely so that least count could be reduced ?*

(5) *Two screw gauges are given to you. One has a least count 0.1 mm and the other has a least count 0.005 mm. Which of these two do you think is more accurate ?*

1.5 Another way of using a screw to measure small distances.

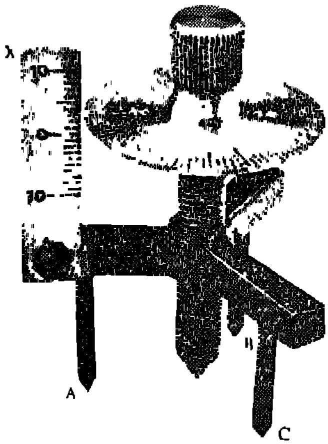


Fig 1 12

You can use the screw in another way to measure small distances. Look at the instrument shown in figure 1. 12.

It has three legs ABC, which are fixed. The tips of these three legs are in the same level. The fourth leg which is centrally situated is a screw which is movable. On top of this screw, a circular scale is fixed. There is a small linear scale XY. You can determine the pitch of the screw and least count as before. Now take this instrument and place it on a glass plate. The three legs touch the glass plate as their tips are in the same level. The fourth central leg is above the surface. In this position ,you can slide the instrument on the glass plate as a whole. Turn the screw in and find out what happens. If the tip of the central leg goes below the level of the tips of the other three legs, the instrument can turn freely

about the central leg. Thus you see that if the tip of the central leg is above the level of the tips of the other three legs then the instrument can slide. If, however, the tip of the central leg is below the level of the tips of the three legs then it can be turned. When the tip of the central leg is just in the same level as of the other three legs, the turning just stops. Knowing this, can you determine the thickness of a very small glass plate ? Place the glass plate below the central leg and adjust the screw so that the turning just stops. Take the reading on the linear and the circular scales. Remove the plate. You will now see the tip of the central leg above the level of the three legs. Turn the screw to bring all the four legs in the same level again. Note the number of divisions through which you have to turn the screw. Knowing this, can you determine the thickness of the glass plate ?

Activity

Find the thickness of a blade, at any point away from its edges.

With the help of screw gauges you can at best measure distances as small as 0 001 mm. As you progress in your study of physics and as your experience increases, you will find occasions when you have to measure distances smaller than this, such as one millionth of a centimetre or smaller. Physicists have developed accurate methods of measuring even such small distances such as, say for example, the thickness of an oil film over the surface of water, distance between two atoms in a crystal etc. You will learn about these methods as you advance in your study of physics.

2 MEASUREMENT OF LARGE DISTANCES

2.1 Introduction

In the previous chapter you have seen how distances smaller than a millimetre can be measured. In this section you will learn methods which can be used to measure large distances.

You have used a metre scale to measure the length and breadth of a table or the length and breadth of a room. In measuring the length of a football ground you had some difficulty in using a scale. Think of several alternate methods. The simplest of them is the one using a surveyor's tape. In the absence of a surveyor's tape, you have another method which involves measuring time to cover the distance. Is there any assumption involved in this method ? In this method you have to assume that you cover the same distance in equal intervals of time or that your speed is constant. This assumption is not necessarily valid in certain cases, particularly, when the distance to be measured is very large, say, 1 km or more. It is not likely that over this distance your speed will remain constant. The method, therefore, will give you an idea of the distance rather than the correct distance. Further, it may not be possible to cover the distance between two objects, such as that between a tree beyond a broad river and any point on the opposite bank. Try to develop a method of determining the distance of a distant object even when it is not easily accessible.

2.2 Method of Triangulation

Large distances are very conveniently measured by the method of triangulation. The method described in this section is very similar to the method of triangula-

tion. Try to learn the method by the following experiment. You have an ink-pot in one corner of a room. You want to measure the distance of the ink-pot from A and B as shown in figure 2.1. Place a metre scale

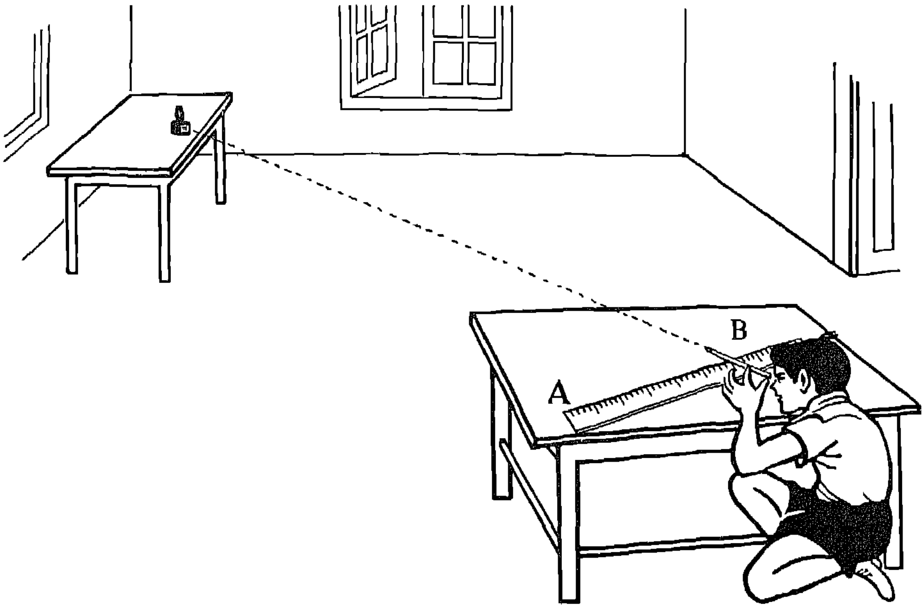


Fig. 2,1

along AB. Place your pencil with one end at A. Rotate it till the pencil points towards the ink-pot. Draw a line in the direction of the pencil AC. Similarly fix

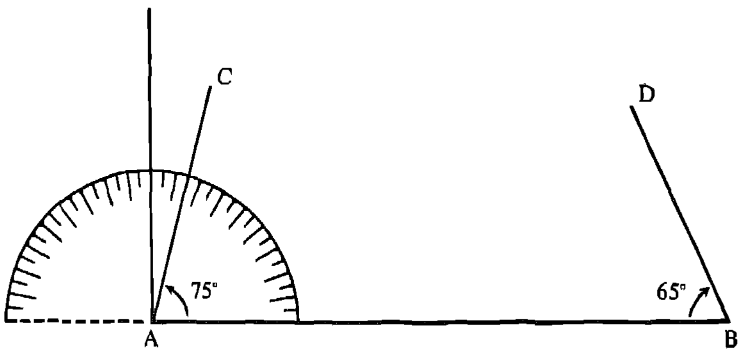


Fig. 2.2

the direction of the ink-pot from B. Let it be along BD as shown in figure 2.2. Where does the ink-pot lie ? Is it on the point of intersection of AC and BD ? If you produce AC and BD you will get the position of the ink-pot. If you try to produce and determine the point of intersection, you will need a paper as long and broad as the length and breadth of the room. It would, therefore, be necessary to scale down the distances. Take a suitable scaling factor such that the reduced figure can be drawn on your paper. Take for example a scale 1 m = 5 cm. Let the distance AB = 1 m. Thus in your scaled down figure, it will be represented by a line whose length is 5 cm. AC is inclined to AB at a certain angle. You measure the angle CAB. Let this be 75°. It means you have to rotate your pencil through 75° so as to change your direction from AB to AC. Put your protractor (angle measurer) with its centre at A and base line along AB. Mark off the position 75° by a point C′ as shown in figure 2.3. In the scaled down figure the ink-pot is along AC′. Repeat the same process with reference to the direction BD. Draw a line inclined to AB at an angle of 65°. Let this direction be BD′. In this figure the ink-pot is along BD′. Produce AC′ and BD′. Let them meet at O′. Measure AO′ and BO′. From this measurement can you determine the distance of the ink-pot from A and B in the above figure ? You will see that you can get the position of the ink-pot without reaching it. Instead of a pencil, a piece of straw will be of greater help, as you can look through the straw and fix the direction accurately.

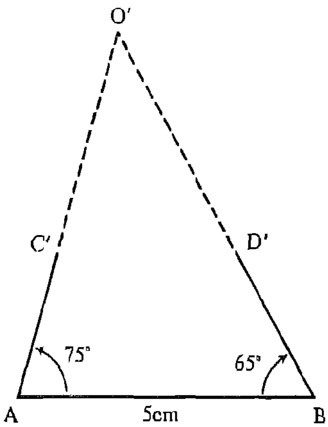


Fig. 2.3

2.3. Straw protractor (Goniometer)

Take two straws AB and CD. Pass a pin through them as shown in figure 2.4. Pass this pin through

the central position O on the base line of a protractor as shown in this figure. Fix the other end of the base line E on the straw AB as shown in the same figure. Now with this device you can measure the angles and fix the direction of distant objects.

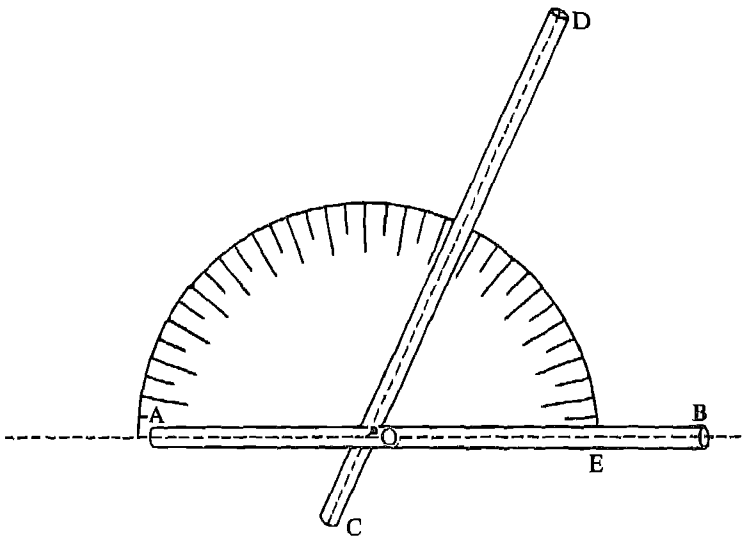


Fig 2.4

Try to see how this method can be used to determine the distance of the pole G of a goal post from the centre P of the football ground. Take the instrument which you have made and place it at P as shown in figure 2.5. Adjust your straw AB to be along the central line. Rotate CD so that on looking through it you can see the pole G. Measure the angle which CD makes with AB. Let this angle be 80°. Walk a distance of 5 metres along the central line to the point Q. Place your instrument at Q and arrange AB to be along PQ and adjust CD so that on looking through CD you see the goal post G. Let the angle be 60°. Can you use these observations to determine the distance PG ? Take the scale 1 m = 1 cm. Determine

PG and compare this with actual measurements taken with the help of a surveyor's tape.

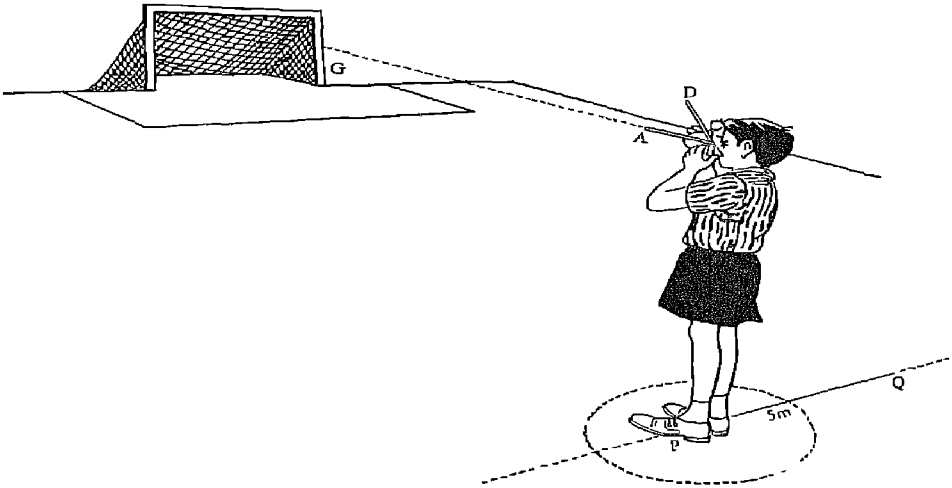


Fig 2 5

Extend this method to determine the distance of a distant tree which you cannot reach and which lies across a stream or a river. Fix a stick at R and

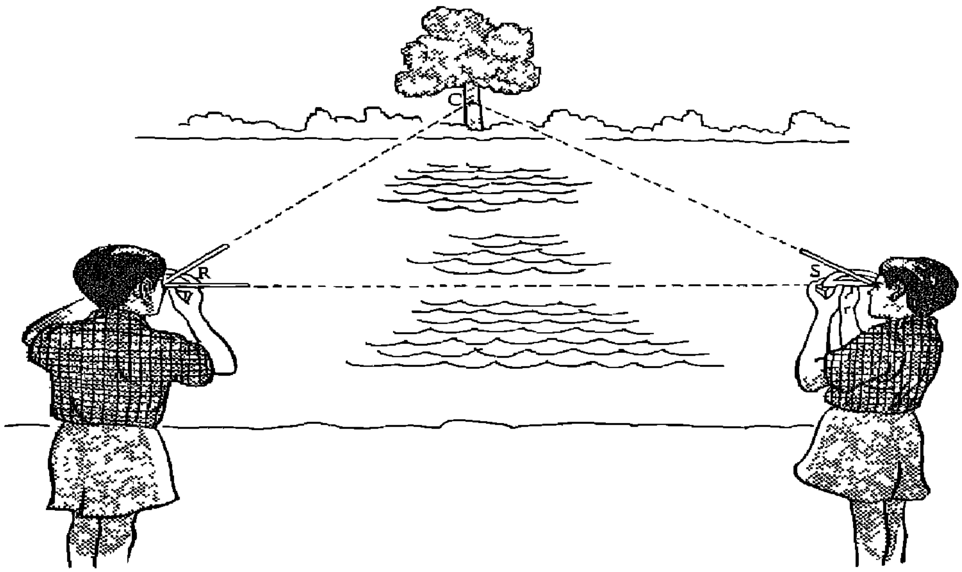
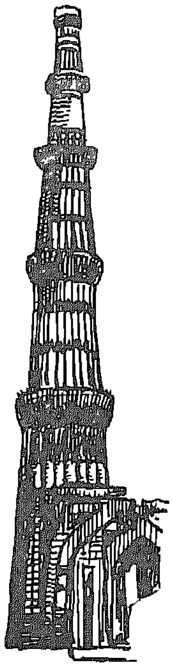


Fig 2.6



another at S some distance away from R along a direction approximately parallel to the river as shown in figure 2.6. With your instrument (straw protractor) determine the direction of the tree at C from R with reference to RS. Do the same thing from S. Measure RS. With these observations can you determine the distance of a distant tree from R or S ?

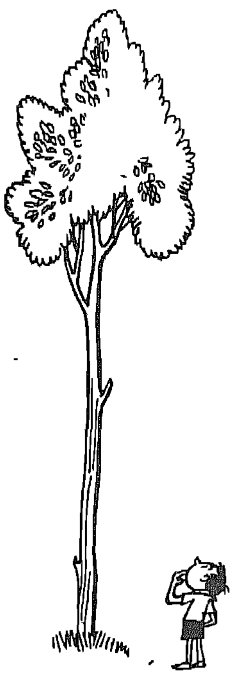
The line RS is often called the *base line*.

Question

The length of a page of your notebook is 25 cm. You want to scale down the distance of a distant object say 100 km in your notebook. What will be the minimum scaling factor ?

2.4. Measurement of the height of tall buildings

Can you modify the method of measuring the distance of a distant object to measure the heights of tall structures such as Qutab Minar, your school building, etc. ? See how you can do this. Let XY in figure 2.7 represent a tall building.



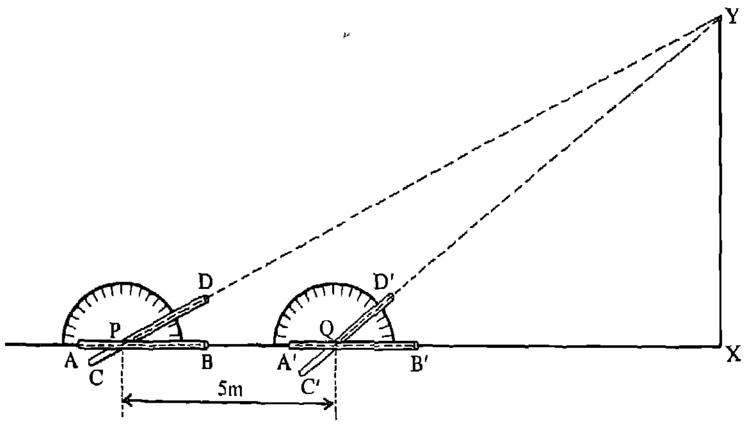
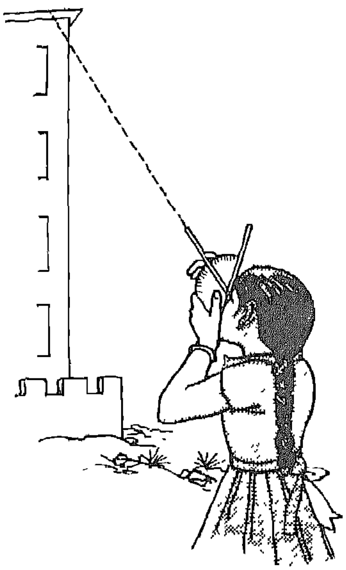


Fig. 2.7

Take a point P on AX where $\angle AXY$ is $90°$. Use your straw protractor for measuring angles.



Adjust the straw AB such that on looking through it, you see the base of the building X. Rotate the straw CD so that on looking through it you see the top of the building Y. Measure the angle which the straw CD makes with the straw AB. Move a distance of 5 m along AX to the point Q. Place the instrument at Q. Arrange AB so that on looking through it you see the base. Adjust CD so that on looking through it, you see the top of the building. Measure the angle which the straw CD makes with AB. From the knowledge of these two angles and the distance PQ, you will be able to determine the height XY. Choose a scale 1 m = 1 cm. Then PQ which is 5 m will be 5 cm on your scaled down figure 2.8. Draw a line

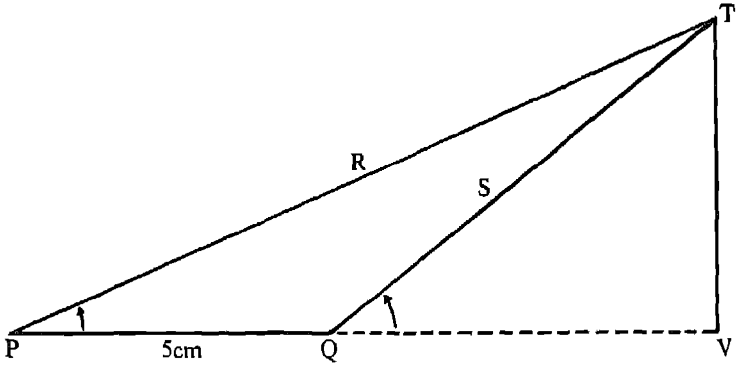


Fig. 2 8

PR which makes an angle TPV with PV equal to DPX of figure 2.7. Similarly draw QS to QV at an angle TQV equal to D'QX. Y is along the direction PR as well as along QS. Thus Y should be the point of intersection of PR and QS. In your scaled down figure T represents the top of the building and V represents its base. Measure TV. Using the scaling factor determine the actual length of the building.

Exercises.

(1) Measure the height of your school building, telegraph pole, light post, etc.

(2) In an experiment to measure the height of Qutab Minar the following observations were recorded. The top was viewed from a certain distance from the base. It was found that it could be seen at an angle of 68°. On walking a distance of 10 m towards the Minar, the top could be seen at an angle of 75°. Determine the height of Qutab Minar.

(3) Take two poles, one twice as long as the other. At about 10 o'clock in the morning and at 2 PM, measure the shadows cast by them. What are the lengths of their shadows ? If you have a stick whose length is not known, from the above observation can you determine its length ?

(4) Based on the length of the shadow, can you determine the length of a tall building ?
You know your height. Stand erect. Ask your friend to measure the length of your shadow. Now measure the length of the shadow cast by a tree. From this observation, determine the height of the tree.

Fig. 2.9

(5) In one experiment, a boy of height 150 cm casts his shadow 50 cm long. A nearby building at the same time has its shadow whose length is 500 cm. Determine the height of the building.

(6) Take a cardboard and make a pin-hole on it. On a window-pane fix two strips of paper 2 cm apart as shown in figure 2.9. Observe the moon through the pin-hole and between two paper strips. Move backwards from the window, still looking at the moon between the paper strips, as much, till you see the moon filling the space between the two strips.

Measure the distance of the cardboard with the pin-hole from the window. From these observations can you calculate the diameter of the moon ?

In one typical experiment, the distance of the cardboard from the window was 110 cm. If the distance of the moon from the earth is 3.8×10^8 m, calculate the radius of the moon.

(7) You have seen earlier in this chapter that you can measure the distance of a distant object using the method of triangulation. Based on this method you may make a *range finder*. The instrument will give you approximately the distance of a distant object. See how this can be done. Take a metre scale and fix two straws one at say, position A and the other at position B. Fix two protractors at both these positions as shown in figure 2.10. View a very distant object, a star, through each of these straws.

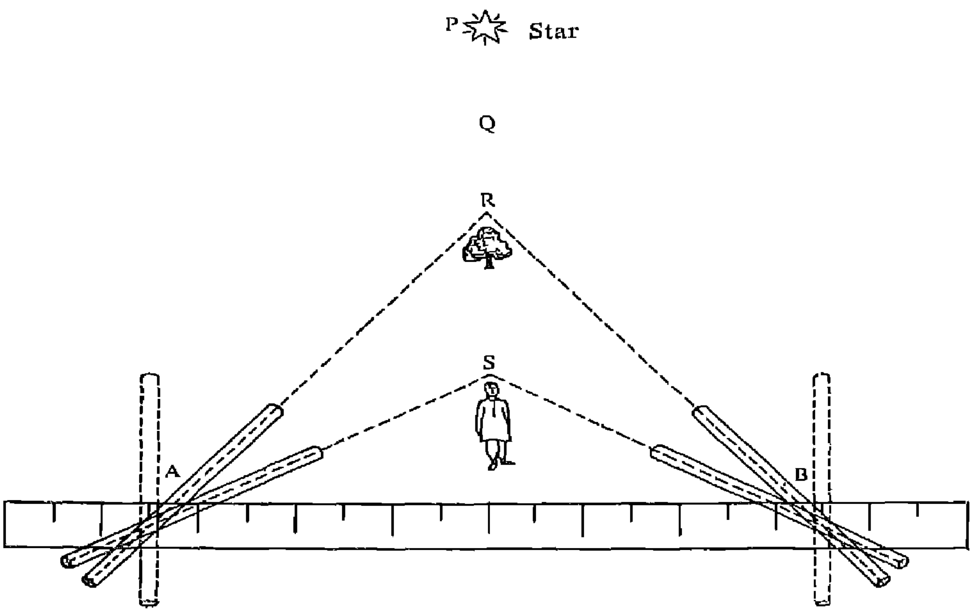
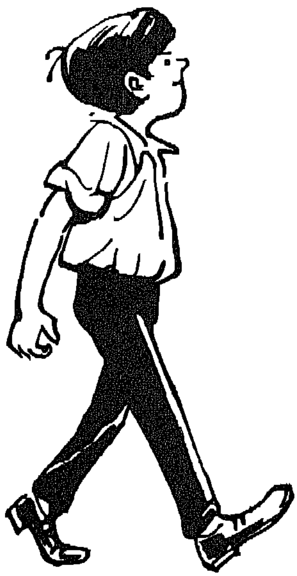


Fig. 2.10

In this case the two straws are almost parallel to each other. If on the other hand you see nearer objects such as 'R', 'S', etc., the two straws are inclined to each other. As the distance of the object increases, the angle between the two straws decreases. Knowing the angles which the straws at A and B make with the scale, can you determine the angle between the two straws ? Now make a range finder of your own and calibrate it by viewing distant objects, such as a light post, tree, etc.



Questions

(1) Have you heard of an expression 'five minutes walk' ? Assume that you walk at a uniform speed of 100 m/min. Express the distance of your house from your school, say 1.5 km in terms of time.

(2) If a motor car moves with a uniform speed of 30 km/h, then can one express a distance of 60 km as 2 car hours ? What would you understand by the ex-expression, 'half an hour's drive' by this car ?

In the examples cited above, you assumed that you walk at a uniform speed of 100 m per minute and a car moves at a uniform speed of 30 km per hour. This assumption is not always true. The speed of a man as well as that of a car changes and, therefore, you can express distances in terms of time only after specifying the speed. You can, therefore, measure the distance by the velocity of sound or light if you know the time and the magnitude of the velocity.

You may have heard echoes from the mountains or tall buildings. Suppose you are a few hundred metres away from a mountain or a building. If you clap loudly and distinctly, you hear your clap again after a short while. This is because, when you clap, you produce sound which moves on. Sound

strikes the sides of the mountain or the building and is reflected back to you. This process takes a certain time depending upon the distance of the mountain or the building and the velocity of sound. The reflection of sound is something similar to the rebound of a tennis ball from the wall. Suppose you hear an echo from a distant mountain after two seconds. This means sound took two seconds to go from you to the mountain and come back to you. In other words, sound took 1 second to reach the mountain. If you know the velocity of sound, you can estimate the distance of the mountain. Velocity of sound in air is 330 m/s.* In the above example, the mountain would be at a distance of 330 m.

Question

Rama standing before a steep mountain, shouted and heard the echo after 3 seconds. How far was the mountain from him ?

Suppose you have a powerful source of light and you have a reflector (mirror) some thousands of kilometres away. The light will take a certain time to reach the mirror and return. Knowing the time taken for the light to be reflected back from a distant mirror, can you find the distance of the mirror from the source of light ?

You must have read that Commander Armstrong of Apollo 11 left a laser beam reflector on the surface of the moon. Scientists from the earth hope to send

*You might remember that the unit of time was expressed as 'sec' in Volume 1. From now on we will follow the recommendation of the International SUN Commission and write 's' for second. Henceforth all Symbols, Units, Notations will be according to the SUN Commission report. The symbols in many cases may be different from other text books.

a laser beam (which is a strong source of light) on to the moon and get it reflected from the mirror placed on the surface of the moon. Knowing the time required for the light to go from the source to the moon and back, they hope to determine correctly the distance of the moon from the earth.

Questions

(1) The distance of the moon from the earth is roughly 3.8×10^8 m. What time will the light take, starting from the earth to get reflected from the moon back to the earth ?

(2) If you know the distance between the light source and the reflector accurately and determine the time required for the light to be reflected back, can you determine the velocity of light ? Foucault, a physicist, used this method to determine the velocity of light accurately. In this experiment the effective distance between the source and the mirror was 20 m and light took 0.12 μ s to come back from the mirror. Can you determine the velocity of light from these observations ?

(3) Have you heard of 'Radar' ? Radar sends out a sort of a beam of light (radiowaves) which travels with the velocity of light. These waves get reflected from obstacles such as aeroplanes in the sky. The reflected waves are received back on the radar screen. The time required for the wave to be reflected back is measured very accurately. From this measurement, the distance of an aeroplane is calculated. In one experiment the radar beam was reflected from an aeroplane. The reflected beam took 10μs to reach the radar screen. Can you calculate the distance of the aeroplane ?

If you succeed in devising a method for measuring the distance of a distant tree from a point without going upto the tree, then you can perhaps with some

modifications use it to measure the distance of a distant star from the earth which also you cannot reach.

The distance of the nearest star Proxima Centauri X is approximately $4{\cdot}3 \times 10^{16}$ m. This is a very large number. To express this distance conveniently another unit called *light year* is used. Light travels with a velocity of 3×10^{8} m/s. The distance covered by light in one year is called one light year. This is taken as unit of length in measuring very large distances, such as those of stars and planets from the earth.

Questions

(1) What will be the distance corresponding to one light minute, one light hour, one light day and one light year ?

(2) Express the distances of different planets from the sun in terms of light days, light hours, light minutes or light seconds whichever is convenient.

(3) The distance of Neptune from the sun is 10^{13} m. What time will light from the sun take to reach Neptune ?

(4) The distance of Mercury from the sun is 10^{10} m. What time will light from the sun take to reach Mercury ?

(5) The distance of the earth from the sun is 1.48×10^{11} m. How long does light from the sun take to reach earth ?

If you want to locate the position of a star and measure the distance of the star from the earth, you must have two points on the earth with reference to which the star's direction can be determined. Will two points A and B on the earth separated by a distance of say 5, 100 or even 1000 m serve your

purpose ? If not, why not ? Is it because the direction of the star from A and B, even when AB = 1000 m, will be practically parallel and these two directions on your scaled down figure will never meet ? You must therefore take two points A and B such that the direction of the star from A makes an angle with the direction of the star from B. Further it should be possible to draw the scaled down figure on the paper. No two points on the surface of the earth satisfy these conditions. Does it mean that you cannot measure the distance of a distant star ? There is a way out of this difficulty. You know that the earth revolves round the sun in an orbit once in a year. From the knowledge of the orbit of the earth round the sun, you can know the position of the earth at A on a particular day. Where will it be six months later ? The position of the earth six months later at A′ (figure 2.11) can be known. You thus have two fixed points A and A′ separated sufficiently far apart with reference to which the direction of a star can be determined. Once these directions are known, you can use your method to determine the distance of a star from either A or B.

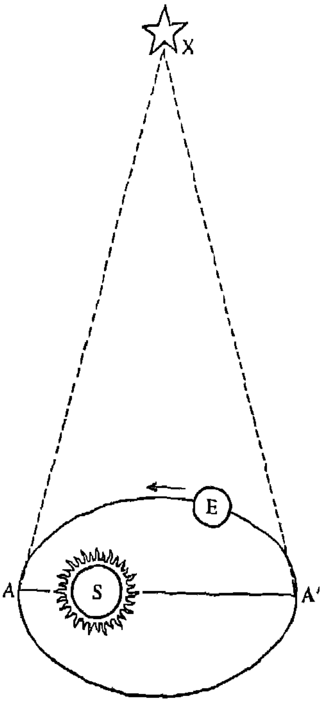


Fig 2.11

Question

You know that the planets such as Mars, Mercury, Jupiter, Saturn also move round the sun. Can you use the above method to measure the distance of a distant planet ?

In one typical observation of the nearest star, Proxima Centauri X, as shown in figure 2.11, the angle XAA′ was 89° 59′ 59″. The angle XA′A was 89° 59′ 59″. The distance AA′ was 297,616,000,000 m. Using the method mentioned above, the distance of the star was found to be nearly $4{\cdot}3 \times 10^{16}$ m.

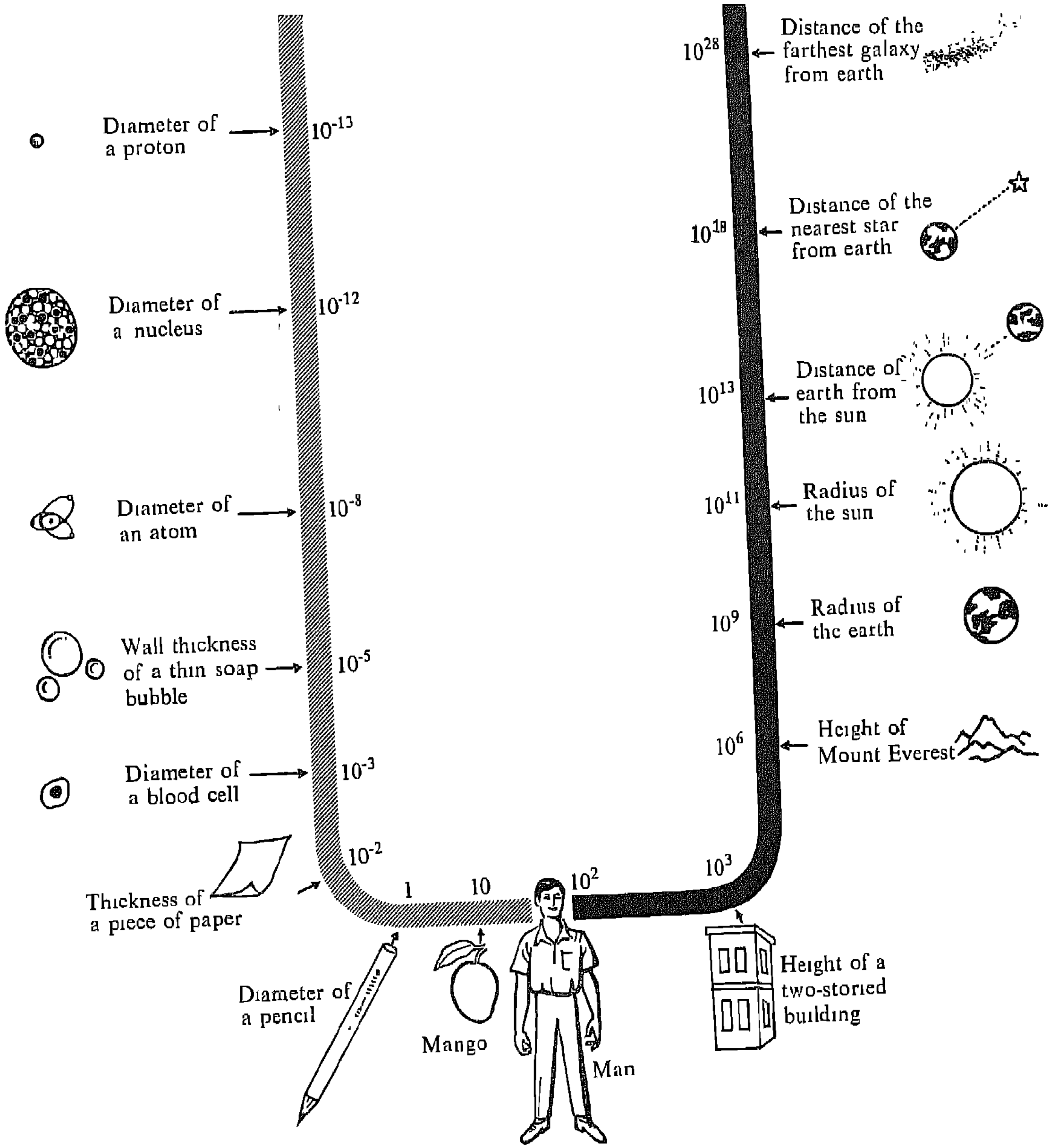
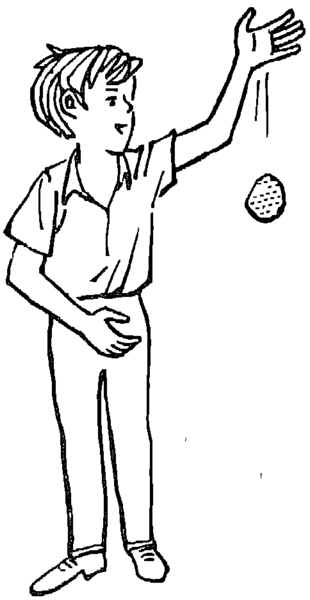


Fig 2.12 Order of magnitudes of different objects in centimetres. The measures are not necessarily exact.

3 MEASUREMENT OF SMALL INTERVALS OF TIME

3.1 Introduction

You know that measurement of any time interval involves the comparison of that time interval with a known one which is taken as a unit. The known time intervals were provided by repetitive phenomena, such as the time interval between the two longest days ; the interval between a sunrise and the next ; the interval between two pulse beats or heart beats ; the time interval required to empty a certain volume of water in a jar through a tube ; the time of oscillation of a simple pendulum, etc. Based on these repetitive phenomena, you can devise several time measuring devices such as the sun-dial, water-clock, pendulum-clock, etc. You know that the sun-dial can mark the time of a day. The water-clock provides a known time interval of the order of a few minutes whereas pendulum clocks provide time intervals of the order of a few seconds. In your common experience you come across situations where some phenomena may be completed within a time interval which is a small fraction of a second. If you want to measure these time intervals, can you use any of these devices ? If you cannot use them, can you think of any other device which can measure time intervals of the order of 1/10 s or 1/100 s ? Before you answer these questions, try and find out which are the phenomena which are completed within a time interval of that order.



Activity

(1) Take a piece of stone in your hand and drop it. It takes a certain time for the stone to fall to the floor. This is a very small time interval, which you may perhaps like to measure.

(2) Support a bicycle on its stand. If you now move the pedal, the rear wheel rotates. You may as well like to measure the time required for the wheel to rotate through one complete revolution.

(3) Switch on an electric fan, the blades of which rotate round a certain axis. It may be of interest to find out the time required for one complete rotation of the blades of the fan.

(4) In fact you can think of time intervals which are even smaller than those mentioned above. For example, the time required for the winking of an eye ; the time required for the wings of a bird to flutter ; the time required for a ray of light to travel across the room.

Question

Two friends stand at a distance of 100 m. If one friend claps, the other can see him clap and also hear the sound of the clap. What is the time-interval measured by the other friend between the instant he sees his friend clap and the instant he hears the sound of the clap. (Velocity of sound is 330 m/s).

Activity

Take a simple pendulum and suspend it from a stand. Find out the time of oscillation of the pendulum for different lengths of the pendulum. For a given length measure the time for 20 oscillations and therefrom determine the time period. Plot a graph between the square of the time period and the length of the pendulum. From the graph find out the length of the pendulum such that the time period is 2 s, 1 s, $\frac{1}{2}$ s and 1/5th s respectively. From your readings what do you think is the minimum time one can measure with a simple pendulum ? You will see that one cannot use a simple pendulum to measure most of the time intervals mentioned earlier.

3.2 Stop-watch

You know what a stop-watch is. It is perhaps the most simple device for measuring short time intervals. Although the watch itself may be very accurate, it is not suitable for measuring time intervals of the order of 1 second. See why this is so from the following experiments.

Activity

(1) Use a stop-watch to measure the time taken for a ball to fall to the floor from a height of about 2 m. Compare your result with that obtained (a) by your friend, (b) by yourself, when both of you repeat the experiment several times.

(2) Take two stop-watches. On one of them paste a paper as shown in figure 3.1. The hand of the stop-watch rotates round. Now use another stop-watch to measure the time during which the hand of the stop-watch with paper pasted on it, is visible to you. Start the second stop-watch as soon as you see the hand and stop it as soon as the hand disappears. Repeat this several times.

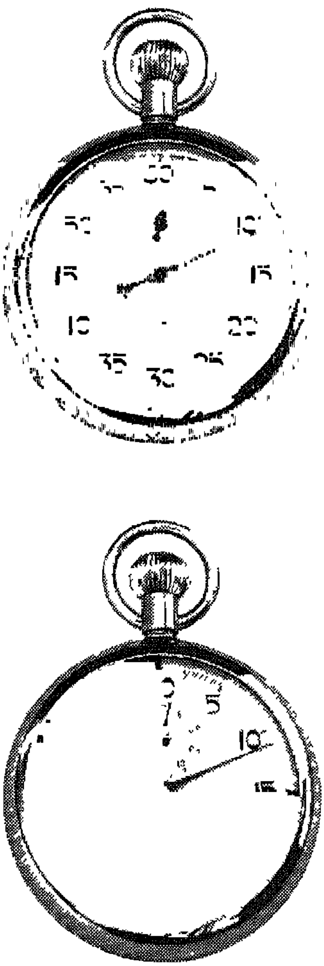


Fig. 3.1

The above experiments will show that when you see something happening you do not react to it immediately. There is a time lag, usually a fraction of a second, which varies from person to person. This is called the reaction time. If, for example, you did not press the stop-watch button in the last activity until 0.3 s after the hand appeared, your reaction time would be 0.3 s. Of course if you also took 0.3 s to press the button after the hand disappeared, you measure the time interval correctly by accident. Human reaction times are, however, rarely as consistent as this, particularly when the conditions are different as at the beginning and at the end of the time interval. In this experiment you have no warning of the hand's "appearance" but you can see when it is "about to disappear". This will affect your reaction time.

Question

Is there any point in having a manually operated stop-watch calibrated to read 1/1000th of a second? Explain your answer.

3.3 Water-timer

Activity

Take a glass bottle with a tube attached as shown in figure 3.2.

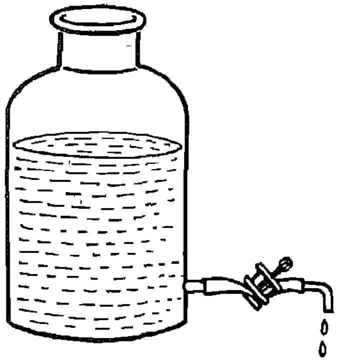


Fig. 3.2

Fill the bottle with water to a certain level and find out the number of drops that fall through the tube in one minute. Change the level of water in the glass bottle and again note down the number of drops per minute. Repeat this for various water levels in the bottle. Plot a graph between the number of drops/min and the level of water in the bottle. You will find that the number of drops/min increases as the level of water in the bottle rises. If somehow you can keep the level of water in the bottle at a fixed level, the number of drops of water falling per minute would be constant. Then this will provide another repetitive phenomenon with reference to which one can determine a time interval.

Make a water-timer as shown in figure 3.3.

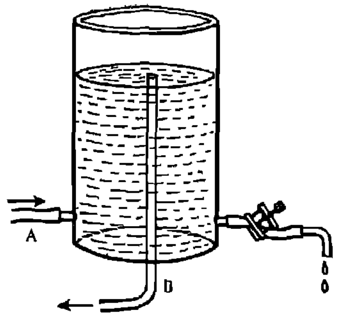


Fig. 3.3

Connect the tube A to the water tap, the tube B to the sink. If you open the tap you will find that the level in the bottle remains the same. Under these circumstances the number of drops falling through the tube per minute is also fixed. In one typical experiment 181 drops fell per minute. It means that the time interval between any two drops is 1/3rd of a second. One can adjust the time interval to even 1/10th of a second by adjusting a few things while constructing the timer.

Question

For a given level in the bottle if you want to change the time interval between two drops from 1/3rd s to 1/10th s, should you increase the diameter of the tube or decrease the diameter ?

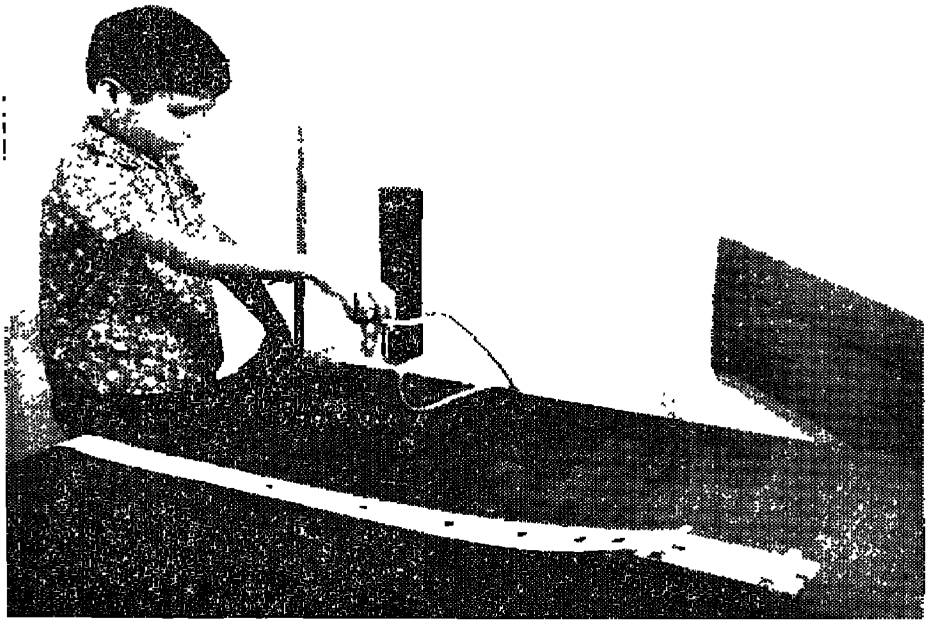


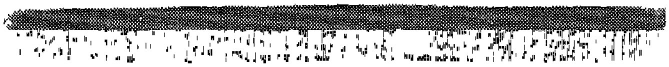
Fig. 3 4

You are provided with one water-timer in your kit capable of measuring an interval of time of 1/3 s. See how one can use such a timer to measure the velocity or acceleration of a trolley. Fix the water-timer in a stand as shown in figure 3.4. Take a trolley and attach a piece of paper tape which is drawn along with the trolley. As the trolley moves the paper is pulled. Coloured water drops fall on the paper at an interval of 1/3rd s. You can, therefore, find out the distance moved in every 1/3rd second.

Questions

The water-timer was fixed and the trolley was made to move. The drops fell on the piece of paper. The markings of the drops on a piece of paper in two different experiments are shown in figure 3.5.

(a)



(b)

Fig 3.5

(1) What do you find from these figures regarding the motion of the trolley in the two cases ?

(2) In the case of (b), can you say which way the paper was pulled when it was attached to an accelerated trolley ?

You thus have a very simple device to mark time in an experiment to measure the velocity and acceleration of a trolley.

3.4 The stroboscope

In the case of a vibrating tuning fork or a rapidly rotating body like the blades of a fan, you cannot count the vibrations or rotations with your eyes. Thus you cannot find their time periods by any of the methods given above which are useful only when the interval of time is greater than 0.1 s. You can, however, measure shorter time intervals by a device called a stroboscope.

Suppose a disc has a black triangle near its edge. Rotate the disc about a horizontal axis passing through its centre. How can you find its time of rotation ? Take a hard-board disc of about the same diameter as the experimental one. Make twelve slits of the same size at equal distances along the edge of the disc as shown in figure 3.6.

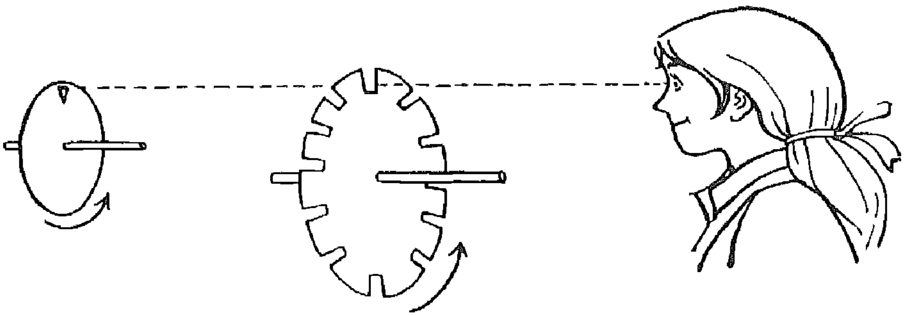


Fig 3.6

Provide the disc with an axle passing through its centre about which it can rotate freely. Such a disc is called a *stroboscopic disc* or a *strobo-disc*.

Let the experimental disc at first be stationary with the black triangle at its highest position. Look at the triangle through one slit of the strobo-disc, other slits being covered with white paper. The line of sight of the triangle is through one slit of the strobo-disc, other slits having been covered with white paper The line of sight of the triangle through the slit is a straight line. Let the experimental disc be rotated at a uniform speed. Look at the triangle through the strobo-slit. The triangle is now seen intermittently. The triangle is visible only when it comes against the slit. Rotate the strobo-disc slowly, slower than the experimental disc. The triangle becomes visible more frequently. Now increase the speed of rotation of the strobo-disc gradually. At a particular speed the triangle appears stationary even though it has not actually stopped moving. Why does the triangle appear stationary ? How is the speed of the strobo-disc related to the speed of the experimental disc ? Try to understand this. When both the discs are rotating, the triangle is visible only when the triangle and the slit come against the eye at the same time. When does this happen ? This can happen when both the discs rotate with the same speed, the time of rotation of the experimental disc is the same as the time of rotation of the strobo-disc. Are there any other speeds of the strobo-disc at which this can happen ?

Now remove the paper cover from the other slits of the strobo-disc. Repeat the above experiment. You will find that the triangle appears steady even though the strobo-disc is rotated at a much slower speed than before. How does this happen ? In this case a slit comes in between the eye and the moving

triangle twelve times in one rotation of the strobo-disc. If every time a slit is against the eye, the triangle also is there, it will naturally appear to be steady. Thus in the time required for one rotation of the strobo-disc, the experimental disc should make twelve rotations so that the triangle and a slit are against the eye at the same time The 'fixing' of the triangle can thus be obtained when the speed of rotation of the strobo-disc is 1/12th of the speed of the experimental disc. This lower speed of rotation of the strobo-disc can be measured by simple methods.

Question

If the experimental disc has two equidistant triangles along its diameter, what should be the speed of the strobo-disc ?

Activity

(1) You are supplied with an electric motor in your kit. Attach a small card-board disc to the axle of the motor. Run the motor. The disc begins to rotate. You can adjust the speed of rotation of the disc by controlling the current in the motor in the same manner as the speed of a fan is adjusted. Use the hand stroboscope and find the speed of rotation of the disc. Repeat this for different speeds of the disc.

(2) In summer you use an electric table fan or a ceiling fan. Use the stroboscope to find the speed at which the blades

rotate. Repeat this for the different settings of the speed regulator of the fan. What is the maximum and the minimum speed with which the blades move ?

(3) Take a strobo-disc and look at a lighted fluorescent tube. Play with the disc and find out whether the light from the tube is flickering or not and if it is flickering, at what rate does it flicker.

(4) Support a bicycle on its stand so that the rear wheel moves freely. Move the pedals so that the wheel rotates at a uniform speed. Measure the speed of rotation of the wheel with the help of a stroboscope. Tie a small flag to a spoke. This would help in determining the speed of rotation.

(5) Fix a hacksaw blade to the edge of a table with the help of a clamp. Move the free end of the blade a little away and release it. The end vibrates to and fro. Can you find out the rate of vibration with the help of your stroboscope ?

You thus see that the stroboscope helps you to observe repetitive events occurring quickly and also helps in measuring the small time interval during which the event occurs. Can you use the stroboscope to measure a small time interval such as the time taken by the stone to fall from your hand to the ground ?

3.5 Flash photography

There are certain events which take place in a very short interval of time. A stone or a bullet hitting a glass pane breaks it. Two cars colliding with each other suffer a damage. All these take place within twinkling of an eye. How can you measure the time intervals in the above cases ?

Activity

Take a stroboscope disc and fix it to a stand. Place a torch and the stop-watch on the two sides of the disc as shown in figure 3.7.

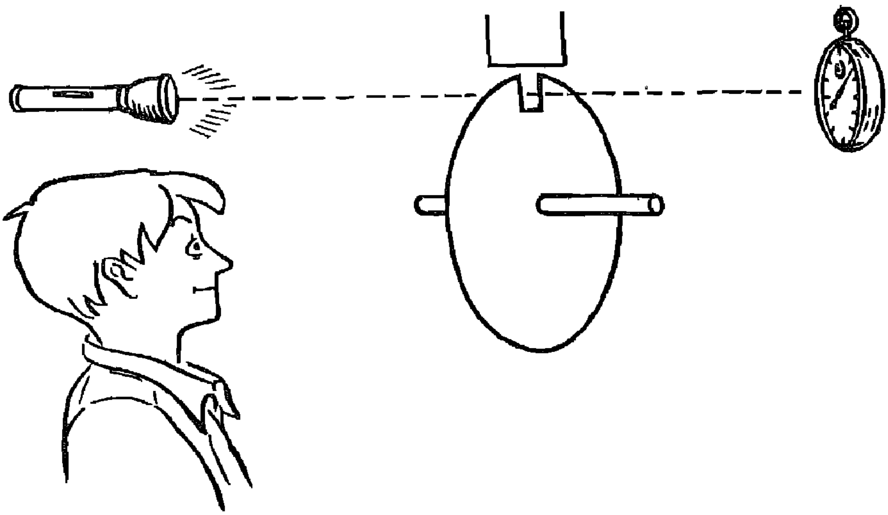


Fig. 3.7

When the slit in the disc, the torch and the watch are in one line, the light from the torch falls on the watch and you can see the hand of the watch Now rotate the disc. Everytime the light falls on the watch you will see the hand in a different position, but in each position it appears to be steady. Thus the movement of the hand appears to

be broken into a succession of steady positions by using the intermittent light.

This could be done in another way. The light is made to fall on the watch continuously. A camera is placed behind the disc in place of the torch and a photograph is obtained everytime the slit passes the watch. In each photograph the hand of the watch appears to be steady.

Questions

(1) *From the time shown in the watch in two consecutive photographs, can you find the time required for one rotation of the disc ?*

(2) *Let the disc have 12 slits and suppose it makes 5 rotations in one minute. What will be the difference in the time shown in the watch in two photographs ?*

These two ways of observing any occurrence have been used in two important techniques. The first is known as the multiple flash photography and the other is the principle of the movie camera. In the flash photography a burst of light is made to fall on the object, say the moving stone, every 1/100th of a second and the photograph of the object is taken on the same film, the camera shutter being kept open throughout. The pictures give an idea of the movement of the object. In the movie camera, the shutter in front of the film opens and closes 24 times in one second and therefore 24 different photographs of the same object are obtained in one second. Thus any change observed from one photograph to other must have occurred within 1/24th of a second. From these pictures the time interval between the occurrence of two events can also be measured.

With multiple flash photography you can take pictures of many objects such as rain drops, flying bullets or fast-moving parts of a machine, which otherwise are difficult to see clearly with your eyes. The difficulty in such cases arises because of a peculiar property of your eyes. Whenever an eye sees an object, it retains the impression of the object for about 1/20th of a second. This is called 'persistence of vision'. The eye is not able to see other things within that time. If two events are to be seen by the eye, the interval between them must be more than 1/20th of a second. Thus any fast moving object is seen blurred by the eye. You observe this effect in a common experience. When a lighted match-stick is moved to and fro quickly, you do not see the lighted end but a streak of light. In a movie, pictures are projected on the screen at the rate of 24 pictures per second. Thus before an impression on the eye produced by one picture is lost, it gets another impression. In this way the impressions merge into each other to produce a continuous movement before your eyes. You can make several interesting toys based on this property of the human eye.

Activity

(1) Fix a card-board piece to a thin metal rod (a knitting needle will serve the purpose) as shown in figure 3.8. Paste a picture of an empty cage on one side of the card-board and a picture of a bird on the other side. Hold the rod between the palms of your hands and slide the palms such that the rod rotates at a high speed. What do you observe? Does the bird appear inside the cage?

(2) Take a small card-board disc. Pass a nail through the centre of the disc. The disc can now rotate about the nail Cut the following shapes from a piece of paper. Paste one of them on the disc as shown in figure 3.9. Now rotate the disc about the nail. Do you see something interesting? Repeat this experiment using the different shapes you have cut from a paper. You may paint the different parts of the design in different colours and repeat the experiment.

(3) Divide the circular disc into seven segments. Paint the different segments in the colours of a rainbow. Now rotate the disc at a high speed. Do you observe the different colours? What has happened to them?

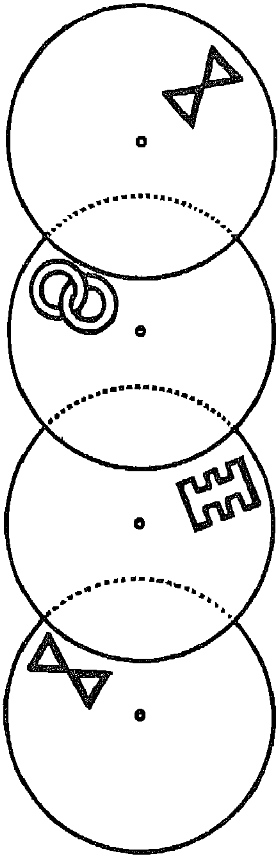
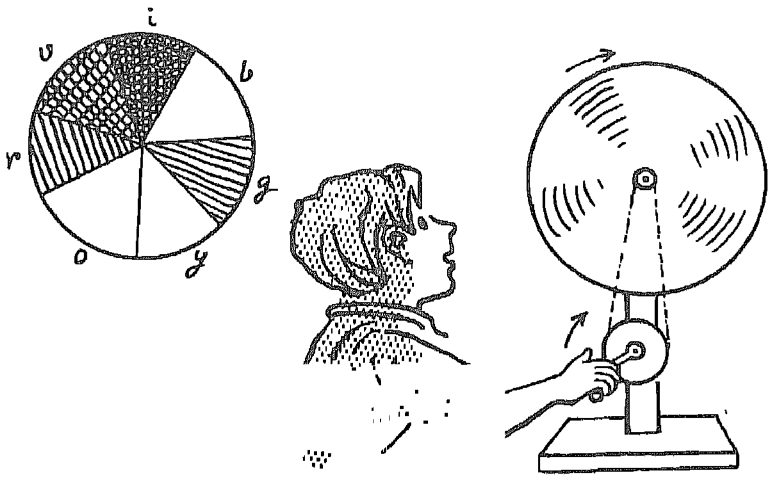


Fig. 3.9



4.1. Introduction.

In your everyday life you see various objects in motion. When you walk, run, jump, dance, ride a bicycle, move in a cart or in a motor car or fly in an aeroplane, you are in a state of motion. On the playground you kick a football and set it in motion. All these are examples of motion. When the wind blows, the leaves of the trees flutter and you find that some leaves fall. In your body the heart beats and the blood moves through the veins and arteries. From the tiny atoms and molecules to the heavenly bodies—the planets, the stars and the galaxies—all are in motion.

You have read earlier that in a uniform motion a body describes equal distances in equal intervals of time. If the velocity of a body changes with time, the motion of a body is then said to be non-uniform or accelerated. The rate of change of velocity is called *acceleration*.

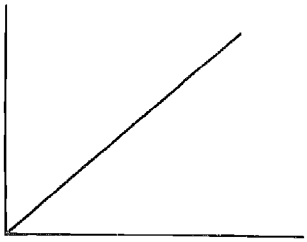


Fig. 4.1

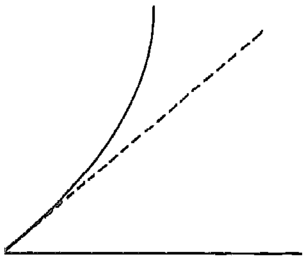


Fig. 4.2

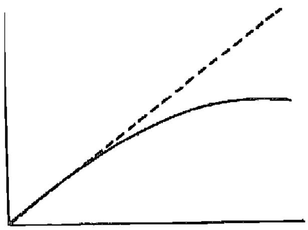


Fig. 4.3

Questions

(1) *Which of the following time-distance relations correspond to uniform and which to non-uniform motion ?*

Table 1

Time in second	*Distance in m*
1	6
2	12
3	18
4	24

Table II

Time in second	*Distance in m*
1	4
2	16
3	36
4	64

(2) *The time-distance relation of a body is represented in three cases by figures 4.1, 4.2 and 4.3.*

State in each of these cases, whether the motion is uniform or accelerated.

(3) The time-velocity graph of a motor car in one typical journey is shown by figures 4.4(a) and 4.4(b). State during which time interval the car has uniform motion and in which time interval it is accelerated. State from figure 4.4(b) after what time does the car come to rest.

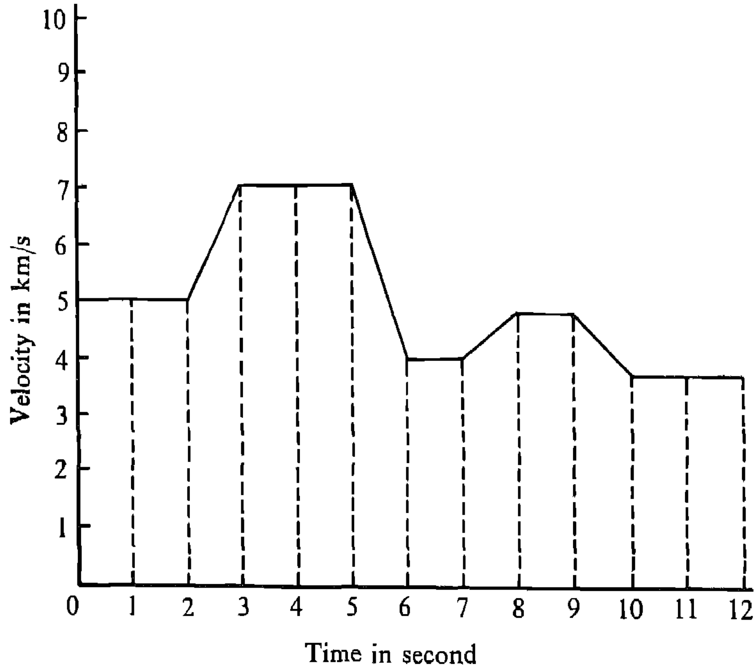


Fig. 4.4(a)

Since acceleration is the rate of change of velocity, it is also a vector quantity.

Acceleration

$$= \frac{\text{Change of velocity in a given time interval}}{\text{Time interval}}$$

The unit of acceleration is

$$\frac{\text{Unit of velocity}}{\text{Unit of time}}$$

$$= \frac{\text{m/s}}{\text{s}} = \text{m/s/s} = \text{m/s}^2$$

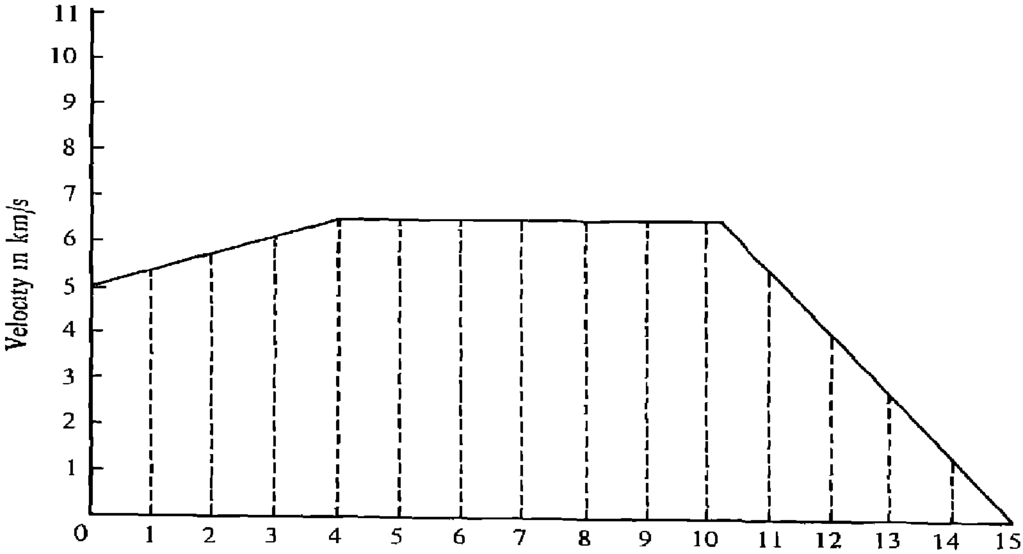


Fig. 4.4 (b)

Activity

(1) Take a long glass plate and place it horizontally on the table. Place a three-wheeled trolley at one end of the glass plate. The wheels should be of small diameter and provided with ball bearing arrangements.
The trolley as shown in figure 4.5 carries a bent stand fixed at the middle. One heavy but hollow pendulum bob with a wide mouth at the top and a small hole at the bottom is suspended from the end of the stand. A brush made of cotton fibre is fixed in the small hole and outside the bob. The brush is so adjusted as to be in contact with the glass plate. Ink is poured in the bob through the wide mouth and it keeps the brush wet.

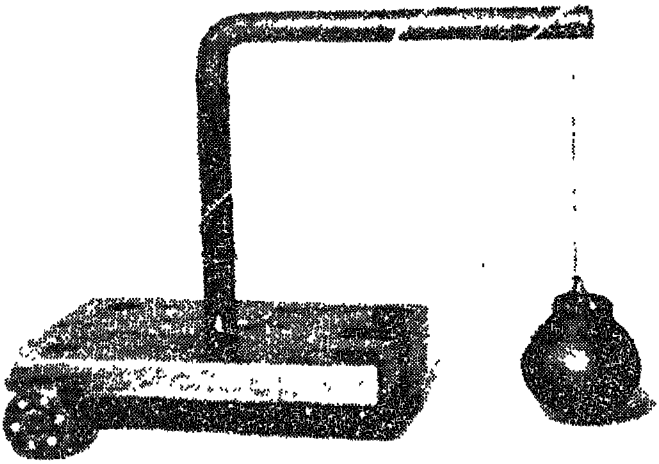


Fig 4.5

Fasten one end of a string to the trolley. Pass the string under a small pulley fixed at the other end of the glass plate and then pass the string over another pulley fixed on a wooden stand so adjusted as to be at a higher level than the first pulley and immediately above it. Tie this end of the string to a pan with weights on it. But hold the trolley from moving under the influence of the weight.

Swing the bob of the pendulum and measure time for 20 oscillations and calculate the time period of the pendulum.

Let the pan hang freely at the end of the string. Swing the bob of the pendulum. The brush of the bob makes impression on the plate while the bob swings. Release the trolley. The brush traces a track when it moves forward (figure 4.6).

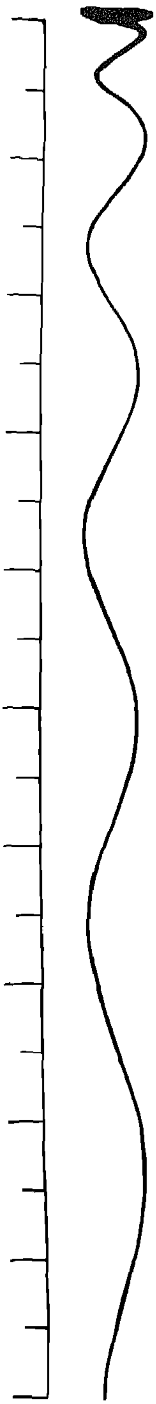


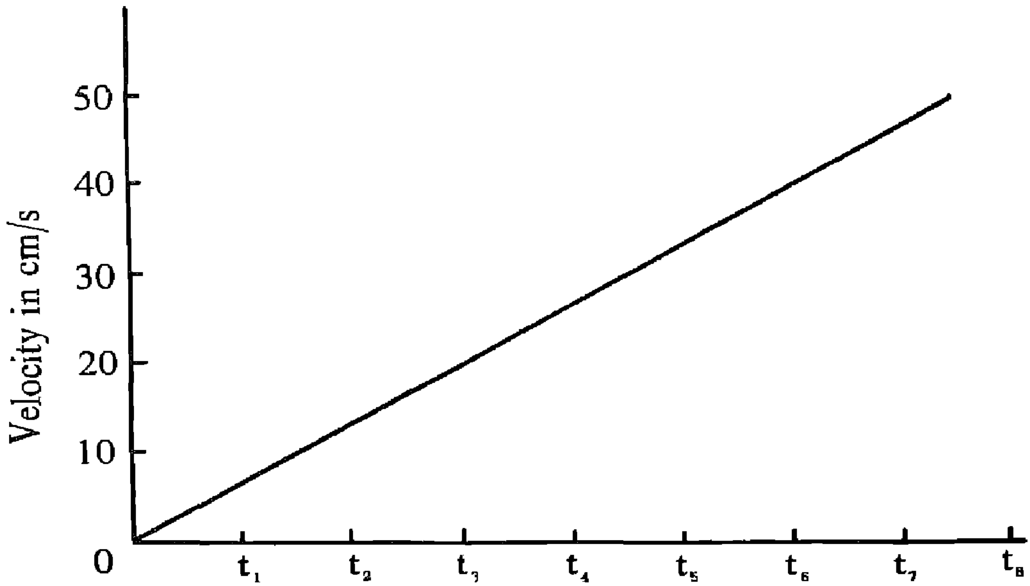
Fig. 4 6

Measure the distance within each full cycle of the track. This distance divided by the time-period will give you velocity. In a typical experiment the following readings were obtained.

Time period of the pendulum = 0.56 s.

No. of cycle	Distance within each cycle in cm	Velocity in cm/s
1	3.9	6.96
2	5 8	10 36
3	8 0	14.28
4	10.2	18.21
5	13.0	23.21
6	16 9	30 18
7	20.0	35.71
8	22.2	39 64

If you plot velocity along Y-axis and time along X-axis, you will get a time-velocity graph as shown in figure 4.7. What type of acceleration do you get, positive or negative ? Is it uniform ?



(2) You can do this experiment replacing the pendulum by a water-timer. Take a trolley, attach a piece of thread to it and pass the thread over a pulley as shown in figure 4.8.

Fig 4.8

Attach a pan at the other end of the thread. Fix a paper tape to the other end of the trolley so that, as the trolley moves, the paper tape is pulled along with it. Fix a water timer as shown in the figure. Put weight on the pan till the trolley just begins to move. As the trolley moves the paper tape is pulled and the water-drops fall at regular intervals on the paper tape. From any drop on its path start counting time and distance. In a typical experiment, the following observations were recorded.

No of drops	Distance from the Starting point O in cm	Time interval between the two drops in s
1	1.5	
2	5.8	
3	13.0	
4	23.0	0.6
5	36.0	
6	51.8	
7	70.6	
8	92.5	

Plot time-distance graph, time-velocity graph and determine the acceleration.

In the above experiments, you see that the velocity of the trolley increases uniformly with time. You can also have a situation in which the velocity of the body decreases with time. If you roll a tennis ball on the ground, you will find that the tennis ball moves but its velocity decreases and finally it comes to rest. In this case the velocity of the body decreases with time. This is also a non-uniform motion.

Fig. 4.9

Activity

(1) Place the trolley with the pendulum on a glass plate. Swing the bob and find its time-period. Attach a spring at one end of the trolley. Press the trolley against a plank fixed vertically at one end of the glass plate and hold the trolley. Swing the bob and release the trolley. The pendulum traces a track as shown in figure 4.9. The readings obtained in a typical experiment are given below.

No. of cycle	Distance within each cycle in cm	Time period of the pendulum in s	Velocity in cm/s
1	5.8		10.54
2	5 7	0 55	10.36
3	4.1		7.45
4	3 4		6.18
5	2.2		4.0

When plotted you will get a graph as shown in figure 4.10. What type of acceleration do you get ? Is it positive or negative ?

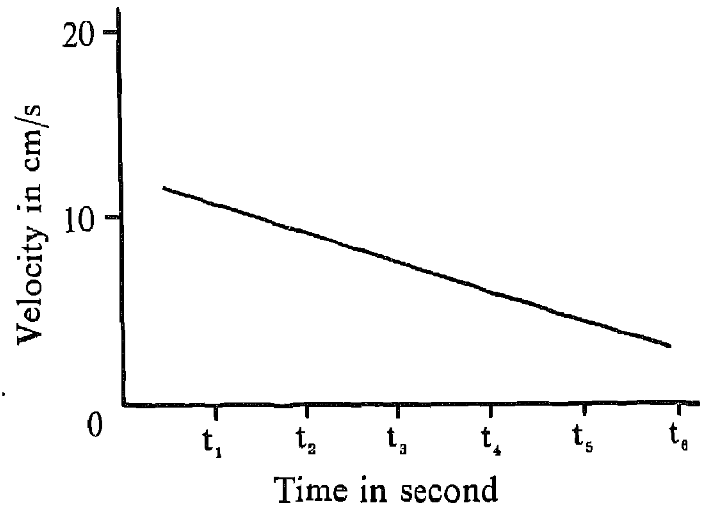


Fig. 4.10

(2) Trake a trolley. Attach a spring at one end and paste one end of a paper tape just adjacent to the spring so that when the trolley moves forward, the paper tape is pulled along with it. Fix a water-timer in a

stand and adjust it so that the coloured water-drops fall on the paper tape as shown in figure 4.11. Fix a wooden plank at the edge of the

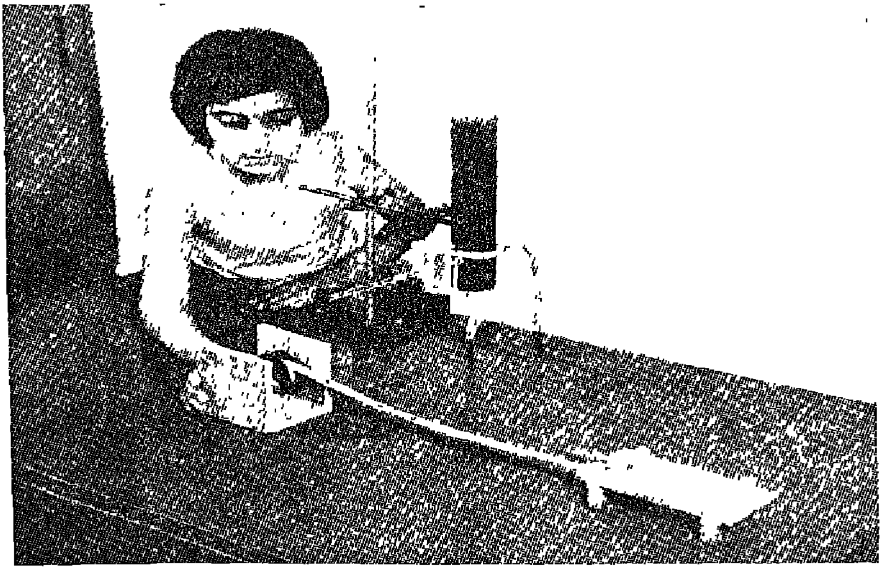
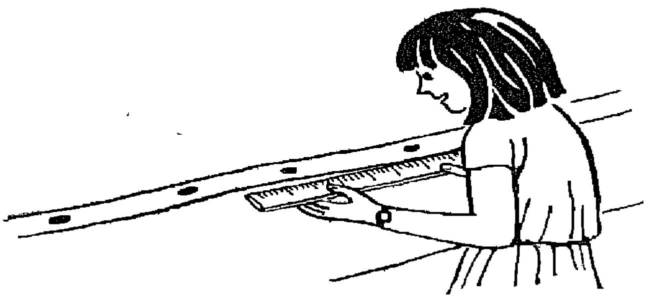


Fig. 4 11

table as before and press the trolley against this plank. Start the water-timer and let go the trolley. What do you find ? You will find that the trolley comes to rest after travelling a certain distance. Mark the position of the drops and find the distance between successive drops. In one such typical experiment following observations were recorded.



No. of drops	Distance from the starting point in cm	Time interval between two drops in s
1	68.6	
2	49.8	
3	34 8	0 6
4	21 1	
5	11.0	
6	3.8	

Plot the time-velocity graph in this case and calculate the acceleration. Is the acceleration positive or negative ? When the acceleration is negative, it is called *retardation* or *deceleration*.

Most of the motions in the universe are non-uniform. In uniform motion, it is easy to determine the distance travelled by a body during a certain time interval. If a body moves with a velocity v for a time t, the distance S travelled by the body is given by,

$$S = v \times t.$$

You can determine the distance travelled from the time-velocity graph. In uniform motion, the time-velocity graph of a body is similar to that shown in figure 4.12. In this case, the distance travelled during 5 seconds will be equal to the area of OABC. Similarly the distance travelled during the time t seconds will be equal to the area of OADE,

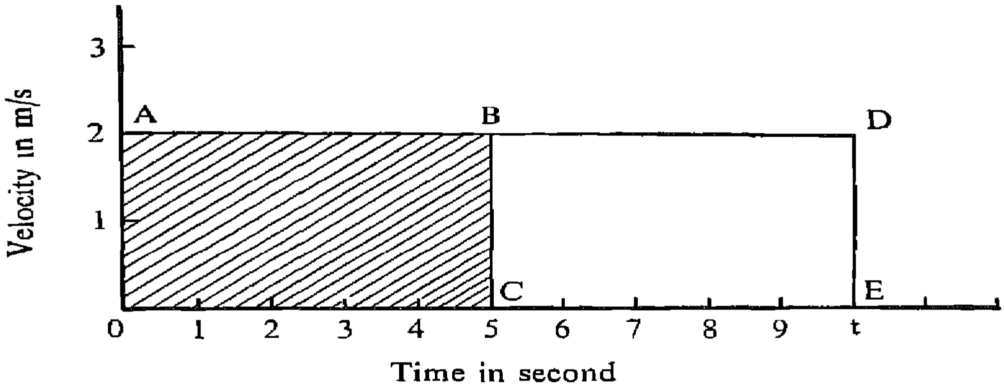


Fig. 4.12

Now try to find out in the case of a non-uniform motion, the distance travelled by a body during a given time interval t. Imagine that the body initially starts with a velocity 'u' m/s. If the acceleration of the body is 'a' metre per second per second, then in every second the velocity of the body increases by a m/s. Thus at the end of one second, the velocity of such a body will be (u+a) m/s. At the end of two seconds, its velocity will be (u + 2a) m/s

Question

What will be the velocity of such a body after 4 and 10 seconds ?

The velocity of this body after a time t seconds would be equal to (u + at) m/s. If you call this velocity v, then you can write this in the form of an equation as $v = u + at$.

Questions

(1) A motor car is moving with a velocity of 10 km/h. If the acceleration that is produced by pressing the accelerator is 10 km/h/h, what will be the velocity of the car after 2 hours ?

(2) *A cyclist starts from rest and begins to paddle. He paddles in such a way that he produces an acceleration of 2 cm/s/s. What will be the velocity of the cyclist after 30 seconds ?*

Now plot a time-velocity graph for an accelerated body. Take a graph paper and plot the velocity along the axis of Y and the time along the axis of X. Start the origin of the velocity axis at u. Let every big division on the graph paper on the Y-axis correspond to 'a' m/s/s and one big division on the X-axis correspond to 1 s. On this graph the point P will have co-ordinates (u + a, 1) as shown in figure 4·13 meaning that after 1 s, the velocity is (u + a) m/s.

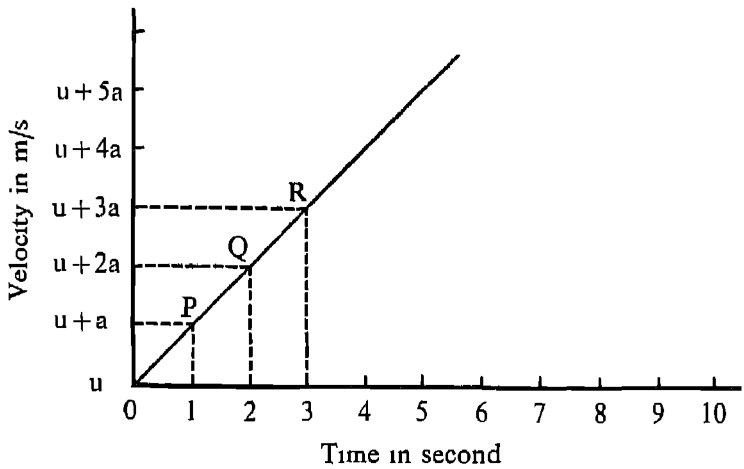


Fig 4.13

Represent by a point on the graph paper the velocity after 2 s, 3 s and so on. Join all these points. What type of graph do you get ? The graph that you obtain is a straight line. Thus, if a time-velocity graph is a straight line inclined to the time axis it represents a non-uniform motion having a definite acceleration.

Question

What will be the nature of the graph if the body has a uniform deceleration ?

Activity

A stone is gently dropped from a certain height. Its velocity increases at the rate of 9.8 m/s/s. Plot the time-velocity graph for the motion of the stone.

It is possible from figure 4.13 to find out the velocity after a certain time interval. You may find out the distance travelled by a body during a given time interval if it is uniformly accelerated. Try to determine this distance. Suppose the body moves initially with the velocity u m/s and it is accelerated by a m/s/s. Its velocity after t seconds will be :

$$v = u + at$$

You see then that this body which was initially moving with the velocity u m/s increases its velocity at a constant rate so that at the end of a time t seconds, its velocity v is equal to $u + at$.

The average velocity V_{av} of this body during the time t seconds will be equal to

$$V_{av} = \frac{u + v}{2}$$

It means that in t seconds the body will cover the same distance if it moves with this uniform average velocity. You know that if a body moves with uniform velocity V_{av} for a time t seconds, then the distance travelled is given by

$$S = (V_{av} \times t)$$

Substituting the value of V_{av},

$$S = \left(\frac{u+v}{2}\right) \times t$$

But $\quad v = u + at$

Therefore $\quad S = \frac{u + (u + at)}{2} \times t$

Or $\quad S = ut + \frac{1}{2} at^2$

Thus you see that if a body is uniformly accelerated by a m/s/s and is initially moving with a velocity u m/s, it will cover the distance S in t seconds where

$$S = ut + \frac{1}{2} at^2$$

Activity.

(1) A body is moving with a velocity u cm/s. It is accelerated by a m/s/s. What will be the velocity of the body after 1 second? What will be the velocity of the body after 2 seconds? What will be its average velocity during 2 seconds? What will be the distance travelled by the body during 2 seconds?

(2) A tennis ball is made to roll on the ground with a velocity of 10 cm/s. Its velocity decreases uniformly at a rate of 4 cm/s/s. What will be its velocity after 2 seconds? What will be its average velocity during 2 seconds? What will be the distance travelled by the ball during 2 seconds?

(3) A stone is thrown up with a velocity of 10 m/s. If the velocity decreases with uniform rate of 9.8 m/s/s, what will be the distance travelled by the stone during 1 second.

The time-velocity graph for a uniform motion is shown in figure 4.14. In any interval, say 1st interval

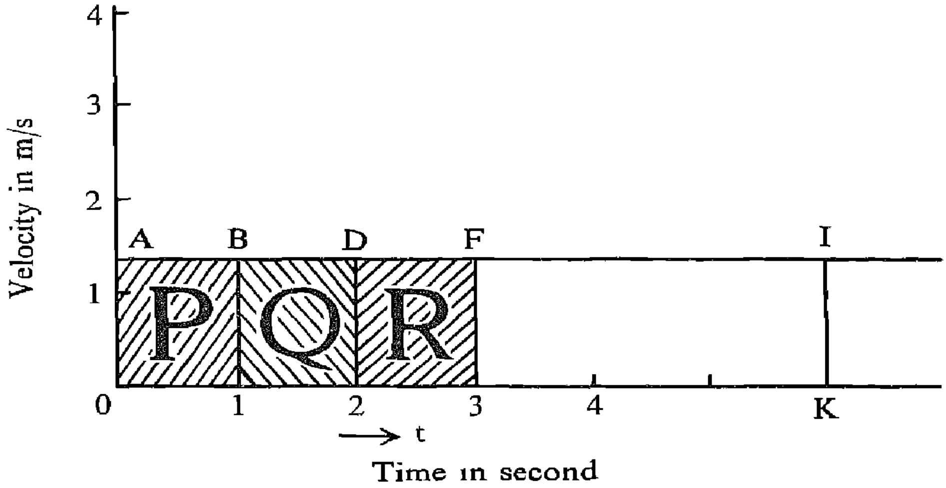


Fig. 4 14

the height of the graph OA gives the speed during the interval and the horizontal length gives you the time. Thus the product of v and time is equal to the product of height and the base or the area P under the line AB. Similarly during the second interval, the product of v and t is equal to the product of height and the base or the area Q under the line BD and so on.

Thus you see that by adding all these areas one can know the distance travelled in say, 4 seconds, 5 seconds and so on.

Now apply the above method to determine the distance travelled in t seconds by a body initially moving with a velocity u m/s and which is accelerated by a m/s/s. The time-velocity graph of such a body is shown in figure 4.15.

Following the method just described, the distance travelled by this body during the time interval t second will be found to be the area of OABC.

You also know that

$BC = (u + at)$ m/s

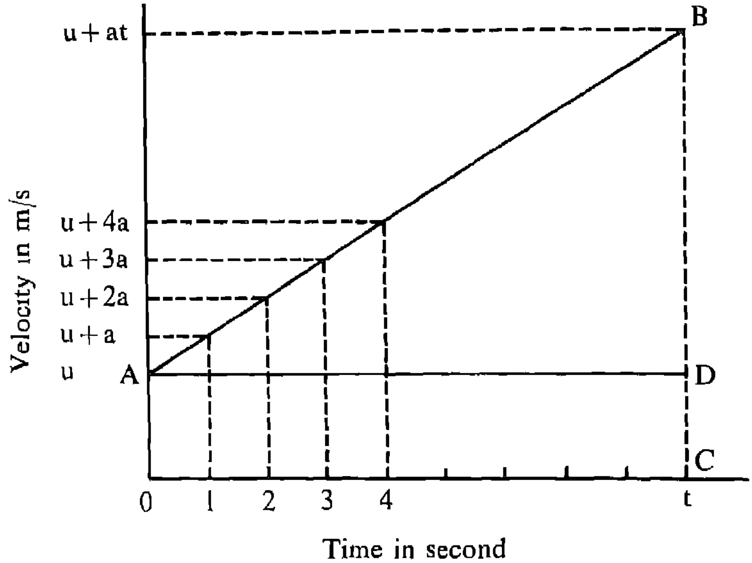


Fig. 4.15

OC = t s

OA = u m/s

The area OABC = area OADC + area BAD

Now OADC is a rectangle and its area is given by base × height which is equal to OA x OC

Therefore area OADC = OA x OC = u m/s x t s = ut m.

BAD is a triangle and its area is given $\frac{1}{2}$ (base x height)

Area BAD = $\frac{1}{2}$ (AD x BD)

= $\frac{1}{2}$ OC s x (BC − CD) m/s

= $\frac{1}{2}$ t s x [(u + at) − u] m/s

= $\frac{1}{2}$ t s × at m/s

= $\frac{1}{2}$ at^2 m

Therefore area OABC = area OADC + area BAD

= ut m + $\frac{1}{2}$ at^2 m.

S = (ut + $\frac{1}{2}$ at^2)m

Or distance S described by the body in time t seconds

= (ut + $\frac{1}{2}$ at^2) m = area OABC.

Exercise.

(1) A motor car is travelling at 20 km/h. After 10 seconds, the velocity becomes 40 km/h. Assuming that the velocity changed at a uniform rate, find the acceleration. Find the distance travelled during 10 seconds ?

(2) The velocity of a body is given at various times t by the following table—

Time t (s)	0	5	10	15	20	30	33	35	40	45	50
Velocity v (m/s)	4	8	12	14	17	20	20	19	17	14	10

Plot a graph between velocity and time and from the graph find out :

(a) the velocity at the end of 25th second ;

(b) the distance travelled during 10 seconds, 20 seconds and 50 seconds.

(3) The following table gives the motion of a cyclist moving with a variable speed :—

Duration of time interval in min	Speed during interval m/min	Distance in m
First 6	180	1,080
Next 18	200	3,600
Next 6	120	720
Next 30	250	7,500
Next 6	120	720

(a) Plot a graph between the speed and time and a graph between distance and time.

(b) From the graph find out when the cyclist is moving fast and when he is moving slow.

(4) A time-speed graph for a car is shown in figure 4.16.

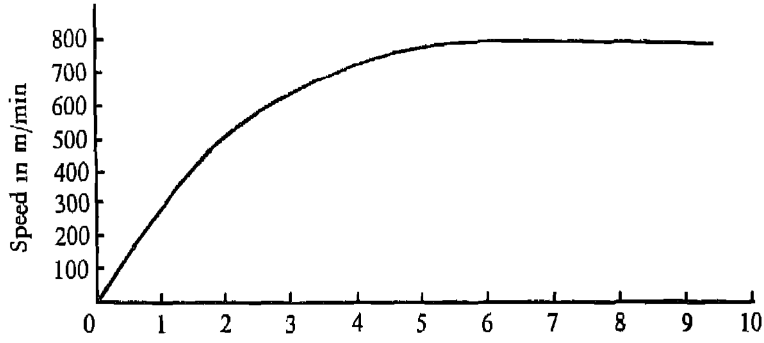
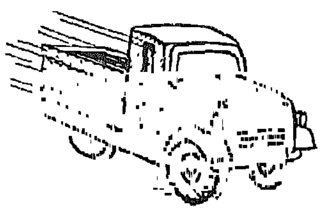


Fig 4.16

(a) Find how far does the car travel in first 4 minutes. Shade the area on the graph.

(b) What does the straight part of the graph signify ?

(5) A train travelling at 60 km/h undergoes a uniform retardation of 10 km/h/h when brakes are applied. Find the time for the train to come to rest and the distance travelled from the place where the brakes are applied.



(6) A truck starting from rest acquires a speed of 30 km/h in 20 seconds. What is the acceleration ? How far does the truck travel during this time ?

(7) A body starting from rest falls freely with an acceleration of 9.8 m/s^2. What is its speed at the end of 1.0 second ? How far does the body fall in 1.0 second ?

(8) A ball is gently dropped from a height of 20 metres. If its velocity increases uniformly at the rate of 9.8 m/s, with what velocity will it strike the ground ? After what time will it strike the ground ?

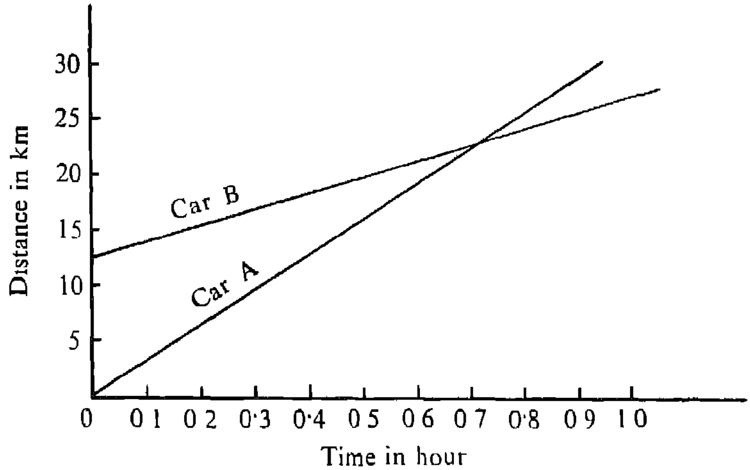


Fig. 4.17

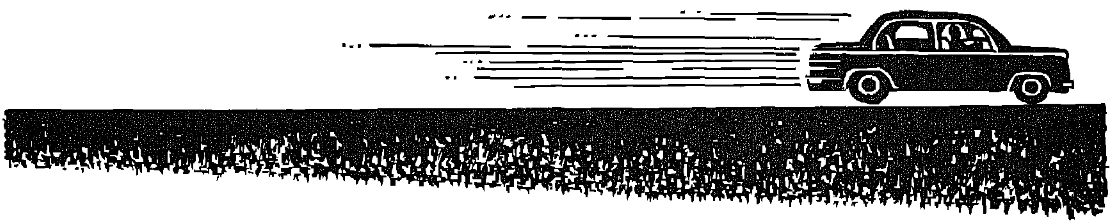
Activity

(1) The figure 4.17 gives the time-distance graph for the two cars A & B. Find out

(a) The speeds of the cars

(b) At what time will car A overtake B ?

(c) From the graph can you tell which car has a greater speed ?

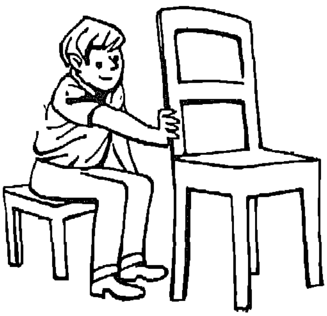


5 FORCE AND MOTION

5.1. Introduction

You know that different types of motion can be classified as either uniform or non-uniform motion. In non-uniform motion, velocity changes with time. But what causes motion and why and how does a body move ?

The objects you see around are either at rest or in some kind of motion. A book on the table, a box in the house, a table in the class room are examples of bodies at rest. A rolling ball, a stone thrown up, a spinning top, the fluttering leaves of trees are examples of bodies in motion. From experience you know that in order to make an object move from its state of rest, you have either to push it or pull it or in some other way apply a force on it. Thus you kick a football to send it flying. You push a chair to move it from one position to another. The wind presses against the leaves to move them.



Closely examine some of the examples that have been stated above. You have a chair at one place. To make it move, you either push it or pull it. That is you apply a force to move it. To move a heavier body you will have to apply a greater force. It also appears that a particular force may not always set a body in motion. For example, when you push an almirah full of books you find that, although you have exerted as large an effort as you can, you cannot make the almirah move. Consider now a few cases where bodies which are in motion are brought to rest by the application of force. A batsman hits a ball

which is set in motion. A fieldsman stops the motion of the ball by either putting his hand or his foot in the path of the moving ball. Effort has to be applied by the fieldsman through his hand or foot to stop the ball. This shows that a force is required to bring a moving body to rest.

A moving cyclist wants to stop his cycle. He applies the brakes and ultimately the cycle comes to rest. Here the force of friction between the brakes and the rim of the wheel brings the moving cycle to rest. So far you have studied the cases of muscular pulls or pushes and frictional forces producing or arresting motion. Now see whether other kinds of forces can do the same.

Question

Name the force which brings a rolling ball to rest.

Try and find out whether other types of forces are capable of causing motion in a body at rest or stopping motion of a moving body.

A stone is just released from a certain height. It falls to the earth because of the pull of the earth. It is a case where a body at rest is brought in motion by the earth's pull.

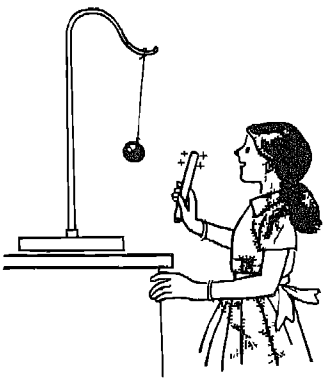


Fig. 5 1

Suspend a pith ball with a piece of thread as in figure 5.1. The ball hangs vertically and is at rest. Charge the ball by touching it with a glass rod previously rubbed with silk. Bring the glass rod near the pith ball. Because of the force of repulsion between similar charges on the ball and the glass rod, the ball is pushed back. This is a case where an electric force has put the ball into motion.

Take a trolley and fix a disc magnet to it. Bring another disc magnet close to the trolley as shown in figure 5.2. What do you observe? You find that

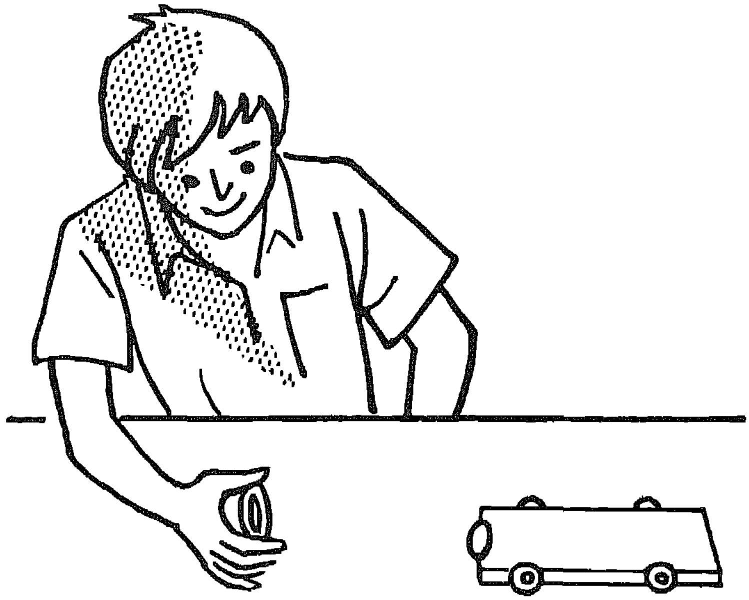


Fig 5 2

the trolley moves either towards you or away from you. The direction of motion depends on the face of the second magnet brought near the magnet attached to the trolley. In this case the magnetic force has put the trolley in motion.

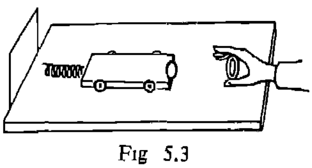


Fig 5.3

Take a trolley to which a magnet has been fixed as before. Attach a spring to the other end of the trolley as shown in figure 5.3. Push the trolley with the spring attached to it against a heavy brick or a wooden plank near the edge of the table so that the spring is compressed (figure 5.3). Now the trolley is in a state of rest. Remove your hand from the trolley. What do you find? You will notice that the trolley moves away from the edge to which it was pressed. In this case the force of compression on the

spring has produced motion in the trolley. The moving trolley can be brought to rest at some intermediate position by holding another disc magnet appropriately. In this case the body is brought to rest because the force of compression due to which the trolley moves forward is balanced by the force of repulsion due to the magnets.

In all the above examples, you have seen that force can cause motion or stop motion. It appears that there must be some connection between force and motion.

Activity

Take the trolley and touch it against the spring which is fixed to the edge of the table as shown in figure 5.4. Press the spring through a small distance and release your hand. The trolley moves away from the spring. Measure the distance through which the trolley moves. Oil the ball-bearings of the wheels of the trolley and press the spring through the same distance as before. Release the trolley. The trolly moves a little more than the previous distance. Measure the distance over which it moves. Place a glass plate on the table and place the trolley over the glass plate. Press the spring again by the same amount and let the trolley move. You will find that in this case the trolley moves still farther. Why does the trolley move through different distances under different conditions ?

To find the answer to the above question, see whether the following experiment helps you. Take the same trolley. Fix a spring balance

to one of its ends as shown in figure 5.5.

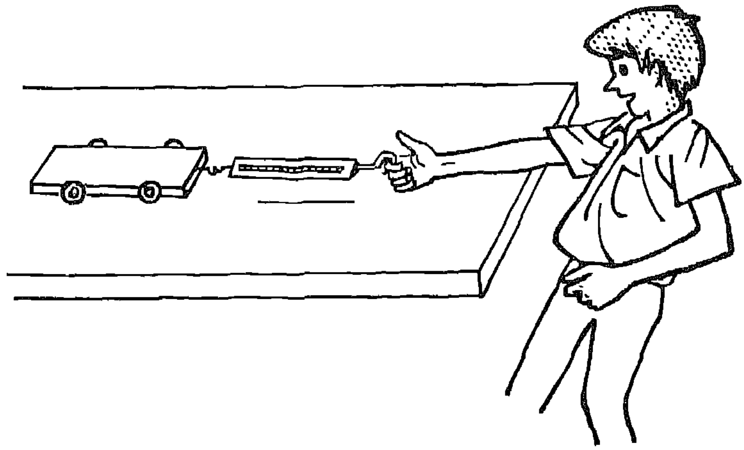


Fig. 5.5

Hold the other end of the spring balance in your hand and slowly pull the trolley. Find out the force required to make the trolley just move. Oil the ball-bearings of the trolley as before and find out the minimum force which makes it move. Place a glass plate as in the previous experiment on the table and find out the minimum force required to move the trolley. Why do you require different forces in these three cases ?

In the above activity the trolley moves over different distances because the friction which opposes the motion of the trolley is different in the three cases. You have seen earlier that when one body moves over the surface of another body, there is friction between the two surfaces in contact. This frictional force opposes the motion and the body is ultimately brought to rest.

Activity

Take a rectangular block of wood having a hook fixed on one of its faces. Place this block lengthwise such that it is in contact with the table top. Connect a spring balance to the hook of the rectangular wooden block as shown in figure 5.6. Pull the spring balance. Does the block slide ? If it does not, pull the balance more till the block begins to slide. Note the extension in the spring. Why does the block slide ?

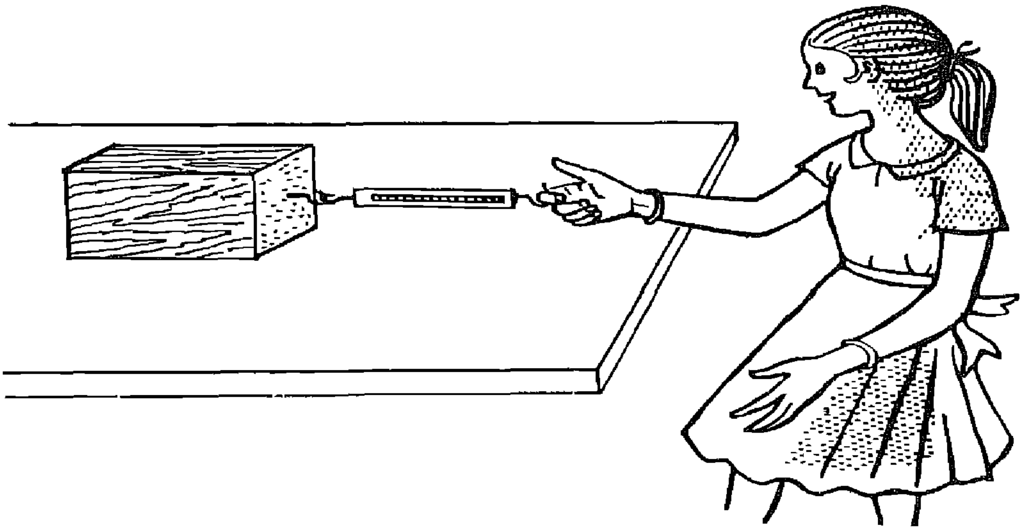


Fig. 5.6

The above experiment shows clearly that when you pull a block of wood, there are two forces acting in opposite directions, the one with which you pull the body and the other, the frictional force which opposes the motion of the body. When your pull is greater than the frictional force the body begins to move. You have seen that when the pull is very small the body does not move. In this case your pull is not strong enough to overcome the friction. As you

increase the pull, the frictional force also increases and balances your pull, but the frictional force cannot increase beyond a certain value. If you pull with a force greater than that then you succeed in pulling the body and setting it in motion.

Question

Why you cannot move a big almirah even when you apply a large effort ?

Activity

Take a rectangular wooden piece about a metre long. Paste a thin strip of white paper with a similar strip of carbon above it on the wooden piece all along its length. Make a small hole near one end of the piece and pass a nail through it. Fix the nail to the wall (figure 5.7). The wooden piece can now oscillate about the nail like a pendulum. With the help of a stop-clock find the time for 20 oscillations of the pendulum. Find out the time taken by the pendulum for one oscillation. Tie one end of a long piece of thread to a marble and the other end to the lower end of the wooden piece over a smooth pulley and hold the marble and the wooden piece as shown in figure 5.7. Now cut the thread at A. The marble and the wooden piece get released at the same time. The marble moves downwards and the wooden piece moves sideways. At the point where the marble strikes the wooden piece, an impression is produced on the paper pasted on the wooden piece. Measure the distance of this mark from the original position of the marble. How much time has the marble

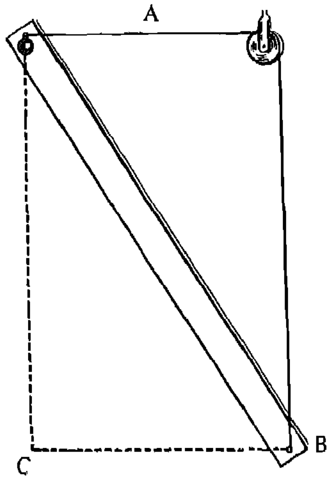


Fig. 5.7

taken to fall through this distance ? Is it the same as that taken by the wooden piece to move from B to C ? How much is this time ? Repeat the experiment with stone, lead sphere, etc., and find out where these weights strike on the wooden piece ? If they strike at the same point every time, what does this suggest ?

The above experiment will clearly show that bodies of different weights take the same time to fall through the same height. This fact was first emphasised by the famous Italian scientist Galileo. He believed that all bodies, heavy or light, when released from the same height fell on the ground at the same time. This concept of Galileo was against the then existing idea that a heavy body would fall earlier. For putting forth this concept Galileo had to suffer ridicule and inquisition. As the story goes he dropped at the same time two bodies—one heavy and the other light—from the Leaning Tower of Pisa in Italy and showed that they fell almost at the same time.

Question

In the above experiment, knowing the time period of the pendulum, can you determine the acceleration with which the body falls ?

Activity.

Take a piece of paper and a ten-paise coin and drop them from the top of your school building. Do they reach the ground at the same time ?

Question.

During storm a fruit and a leaf are separated at the same time from a tree. Do they reach the ground at the same time ?

The results of the paper ten paise coin and the fruit-leaf experiments seem to go against Galileo's concept. Newton repeated these experiments and tried to find out the reasons why in these particular cases Galileo's concept did not appear to be valid. In the process of understanding these phenomena, he did an interesting experiment which is described in the following paragraph.

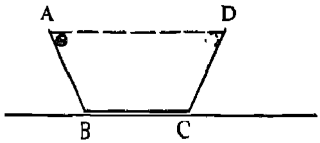


Fig. 5.8 (a)

He took a long tube which could be evacuated. Inside the evacuated tube he arranged so that a penny and a feather could be dropped from one end at the same time and found that when there was no air in the tube, both of them reached the bottom of the tube at the same time. This proved that the resistance offered by the air was responsible for the difference in the time of fall from the same height of a heavy body from that of a lighter body.

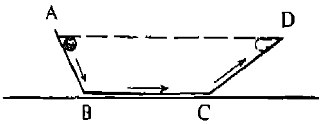


Fig. 5.8 (b)

Activity

Take a long metal strip and make it in the form of a rectangular boat. Fix this on a wooden plank near the centre by means of a nail. Bend the two sides according to the diagrams shown in fiigures 5.8 (a), (b) and (c). In figure 5.8(a), release a marble from the side AB. What do you find ? Does it rise to the same height along the side CD ? What happens to the marble in figure 5.8(b) and figure 5.8(c) ? What do these experiments suggest ?

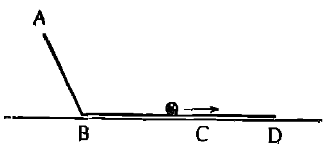


Fig. 5.8 (c)

In figure 5.8(a) the marble moves down the plane with an acceleration and up the plane with a retardation. But along the horizontal plane the marble moves with uniform velocity assuming that there is no friction.

Continuing in this manner you will find that a body moving with uniform velocity will continue to move so long as there is no cause for acceleration. When there is less friction, bodies will move for a longer time with nearly the same velocity. Newton found the general cause for acceleration or retardation in a moving body. He stated that *every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled by an external impressed force to change that state.*

5.2. Inertia

Galileo (1564-1642) and Newton (1642-1727) found out an important and fundamental property of matter, namely its *inertia*, that is, a body at rest or in uniform motion in a straight line continues in that state unless acted upon by an external force. Now try to understand this property of inertia by considering a few common examples.

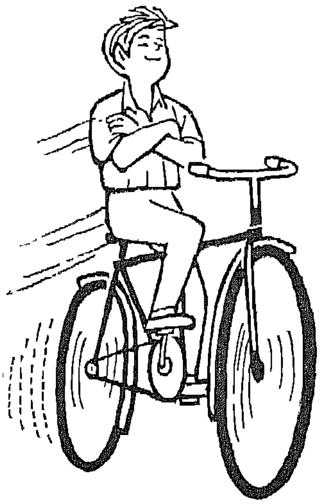
A person sitting in a stationary car feels a backward jerk on the upper part of his body when the vehicle starts suddenly. Also, if the vehicle stops suddenly, the upper portion of the body of the person is thrown forward. Why do these happen ? It is because the person due to inertia continues to remain at rest when the car starts suddenly and hence the backward jerk. In the case of a moving vehicle, the body continues to move even when the vehicle comes to rest and hence the forward jerk. Again, a person getting down from a moving vehicle is likely to be

thrown forward. This is because his upper part continues to move along with the vehicle whereas his feet are abruptly brought to rest on touching the ground. You can give few more examples from your daily experience.

Activity

(1) Take a coin and put it on a card placed just above a hollow cup on a table. Strike the card quickly with a sharp metal strip. What do you find ?

(2) Set a pile of 15 to 20 similar coins. Strike quickly one of the coins near the bottom. Explain what you observe ?



Questions

(1) A bowler runs a few steps before delivering the ball. Explain why ?

(2) An athlete, in long or high jump, runs a few steps before the jump. Explain why ?

(3) If you throw a ball vertically upward in a running train or car, does the ball come back to your hand ?

(4) A cyclist after pedalling enjoys rest, but the cycle moves for sometime, why ?

5.3. Relation between force, mass and acceleration

You have seen that a force is necessary to set a body in motion. A force is also necessary to stop a moving body or to change the motion of the body. You have also observed that a greater force is necessary to move a heavier body like an almirah than a lighter body like a chair. If you throw a cricket ball, it moves fast, but the same force does not make a shot-put ball move quickly. Does it mean that the mass of a body has something to do with the motion produced in it by a given force ?

Activity

Take a spring and fix it to a wooden plank. Fix this plank at one end of a long table as shown in figure 5.9. Place a scale near the

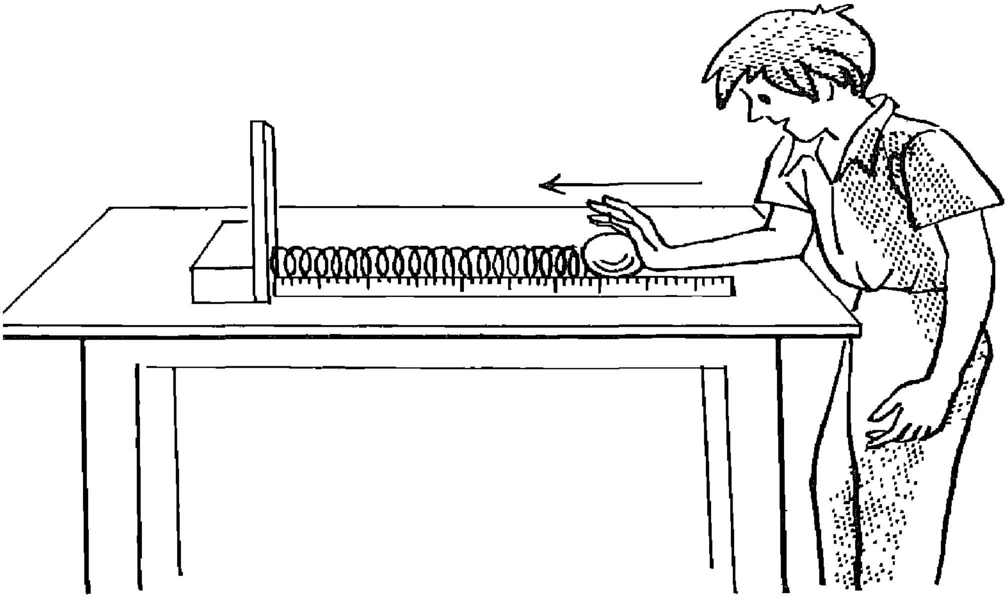


Fig. 5.9

spring. Place a wooden ball against the free end of the spring and press the spring with the help of the ball up to a certain mark on the scale. Now release the ball. The ball moves forward. Note the distance up to which the ball moves on the table. Repeat the experiment using a tennis ball, a paper weight, a marble, each time pressing the spring up to the same mark. Do these different bodies move through different distances ?

Again, press the spring up to a certain mark on the scale. Keep a cricket ball against the free end and release it. Note how far the ball travels. Now repeat the experiment by

compressing the spring to different marks on the scale and note the distance travelled by the ball in each case. Does the ball move the same distance in each case? If not, why?

5.4 Relation between force and acceleration

(1) Place the trolley with the pendulum at one end of a long glass plate. Find the time-period of the pendulum. Fasten one end of a string to the trolley and pass it through two pulleys as you did in the previous chapter. Hang a pan at the other end of the string. Place weights on the pan. Swing the bob and release the trolley. You get a track as before. Repeat the experiment with 5g, 10g and 15g weight on the pan. The weight of the pan plus the weight, if any, placed on it is the applied force. Examine the tracks (figure 5.10). What do you observe? In a typical experiment the following readings were obtained.

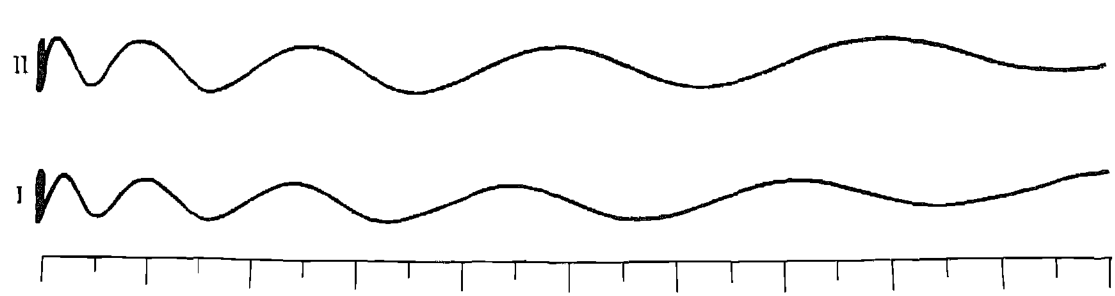


Fig. 5.10

Mass of the trolley with the pendulum = 900 g

Observation	Force	No of cycles	Distance within each cycle in cm	Time period of the pendulum in s	Velocity in cm/s
I	Weight of the pan = 30 g	1 2 3 4	7.8 14.5 20 0 27 0	0.55	14.2 26.4 36.4 49.1
II	Weight of the pan + 5 g = 35 g	1 2 3 4	8.3 16.0 24.0 30 7	0 55	15.1 29.1 43.6 55.8
III	Weight of the pan + 10 g = 40 g	1 2 3 4	9 7 20 0 27 5 37.0	0.55	17.6 36.4 50.0 67.3
IV	Weight of the pan + 15 g = 45 g	1 2 3 4	10 2 21.5 32 0 42.0	0.55	18.6 39.1 58.2 76.4

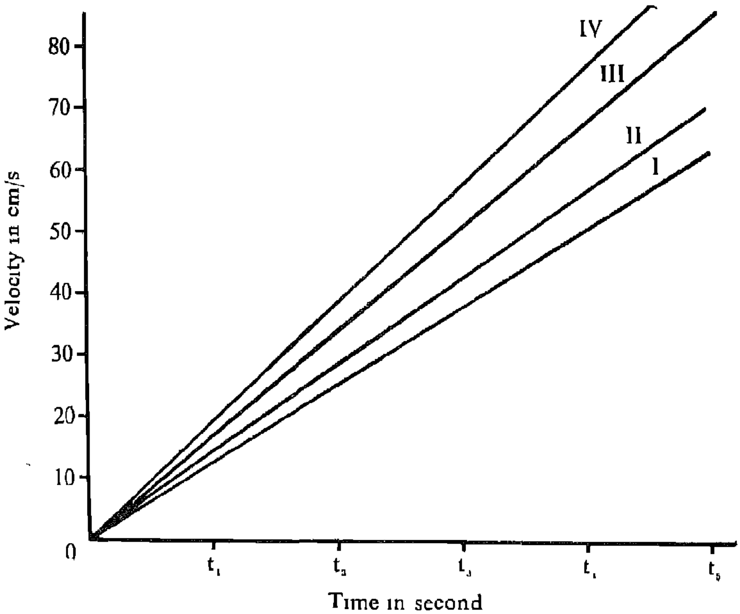


Fig. 5.11

When plotted you will get a time-velocity graph as shown in figure 5.11. Calculate acceleration for each set of observations.

(2) Place a water-timer on the same trolley. Remove the pendulum. Fill this water-timer with coloured water. With the help of a stop-clock, find the time-interval for 100 drops and from this calculate the average time-interval between two drops. Now tie a light thread to the trolley and pass this thread over a pulley clamped near the edge of the table. To this free end of the thread attach a pan as shown in figure 5.12. Now put weight on the pan so that the trolley

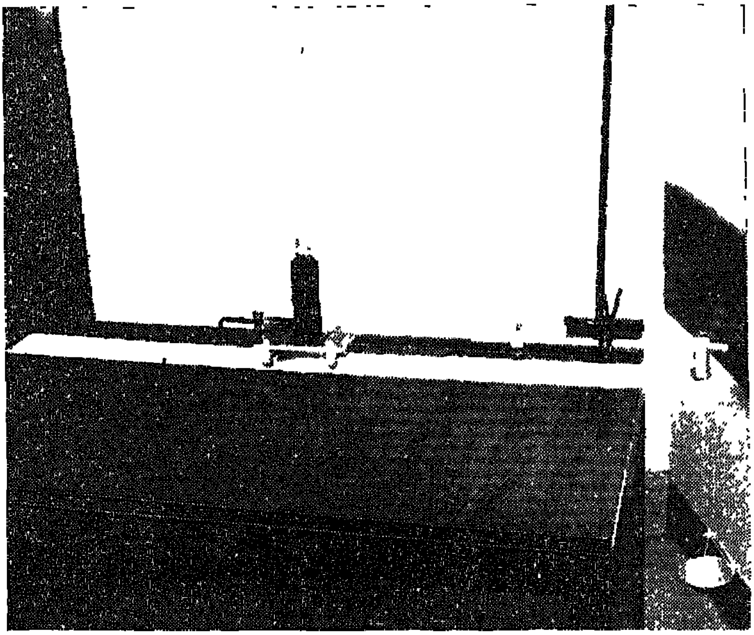


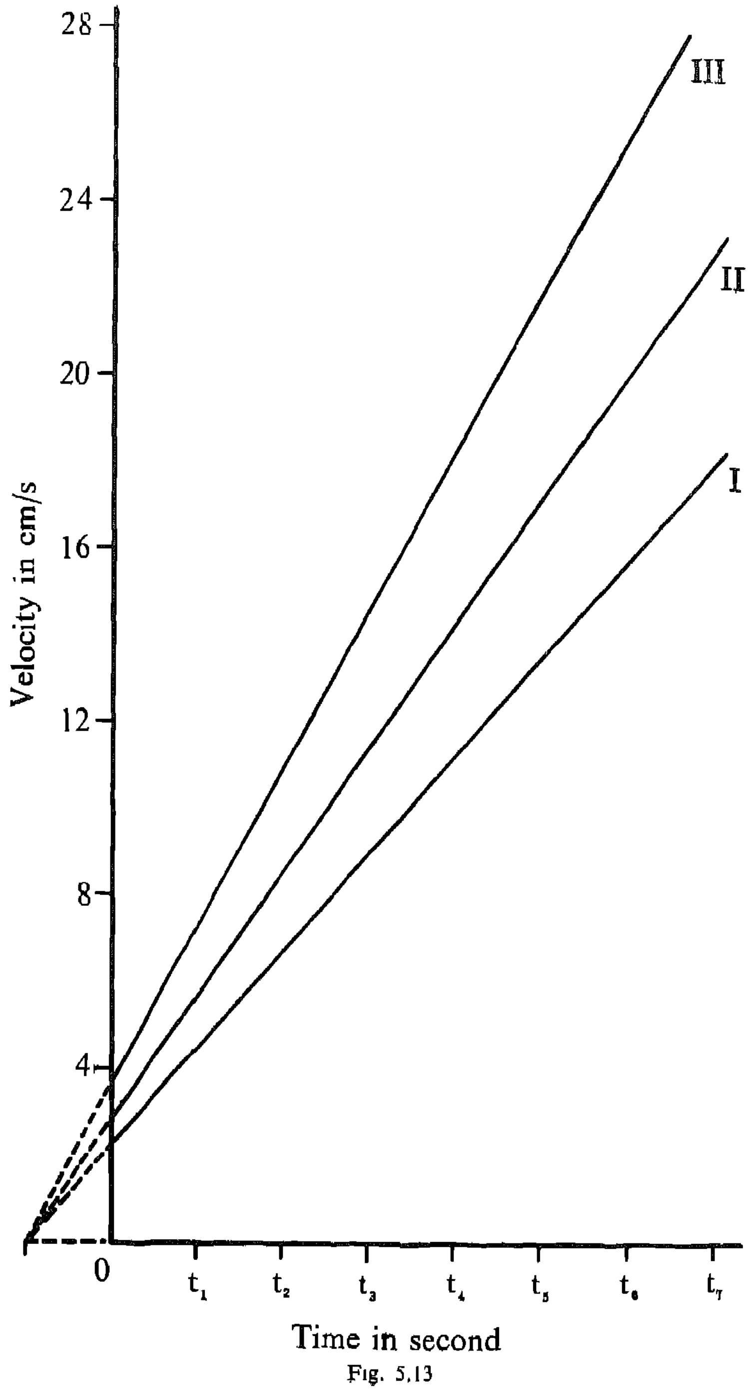
Fig. 5 12

just begins to move. Mark the drops on a sheet of paper kept below the trolley. Find the distance between two consecutive drops as before and calculate the velocity. Repeat the experiment for different values of weights on the pan, that is, for different forces and find the acceleration in each case. In a typical experiment with a trolley the following observations were recorded.

Weight of the trolley including bottle filled with coloured water = (340 + 310) g = 650 g
weight of the pan = 10 g

No. of observation	Force (Pan+ weight added) in g	Distance of the drops from the starting point O in cm	Distance between two consecutive drops in cm	Time interval between the drops in s	Velocity in cm/s
I	10+12 =22	3.0 7.8 14.1 21.7 32.1 43.1 55 7	3.0 4 8 6 3 7.6 10 4 11.0 12 6	0 7	4.3 6.8 9.0 10.8 14 8 15.7 18.0
II	10+18 =28	7.8 18.1 30 3 44.1 60.2	7.8 10.3 10.2 14 8 16.1	0.7	11.1 14.7 14.3 20.1 23.0
III	10+24 =34	7 9 18.3 31.0 46 3 64.1	7.9 10.4 12.7 15.3 17 8	0 7	11.3 14 8 18.1 21.9 25.4

From the above readings draw a time-velocity graph. The nature of the graph will be the same as shown in figure 5.13. Measure distance from the position of any convenient drop. In figure 5.13 the distance has been measured from the second drop. Calculate the acceleration for each set of observations. In actual measurements following values of acceleration were obtained for different forces, i.e. for different weights on the pan.



28
24
20
16
12
8
4
0
Velocity in cm/s
III
II
I
t1
t2
t3
t4
t5
t6
t7
Time in second

Fig. 5.13

No of observation	Force (F) in g (Pan + weight added)	Acceleration (a) in cm/s^2
1	30	20.4
2	35	25.2
3	40	28 8
4	45	35.0

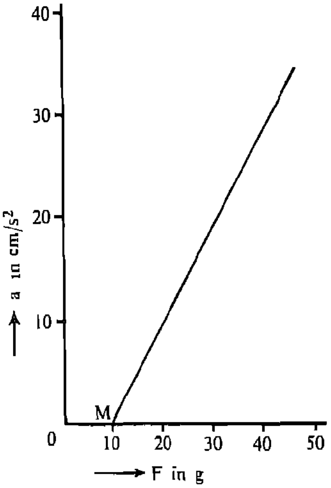


Fig. 5.14

Draw a graph taking force along X-axis and acceleration along Y-axis. You will get a straight line graph (figure 5.14) which cuts the X-axis at the point M. This indicates that even when a force acts on the body, the body has not acquired any acceleration. This force is due to friction and opposes the motion of the body. You have seen before that when you pulled a block of wood on a table with a spring balance, the pointer indicated a force before the body developed any motion. If a force F acts on a body when F′ is the opposing force then the acceleration developed in the body depends on the total acting force F + F′.

When this force acting on the same body increases, its acceleration also increases. In other words, the acceleration is proportional to the acting force.

5.5. Relation between mass and acceleration.

(1) Place the trolley with the pendulum on the glass plate and put a 5 g weight on the pan. Swing the bob and release the trolley. Put successively 0.5 kg, 1 0 kg and 1.5 kg weight blocks on the trolley and repeat the experiment each time. You will get four tracks as shown in figure 5.15. Can you find out a relation between mass and acceleration ?

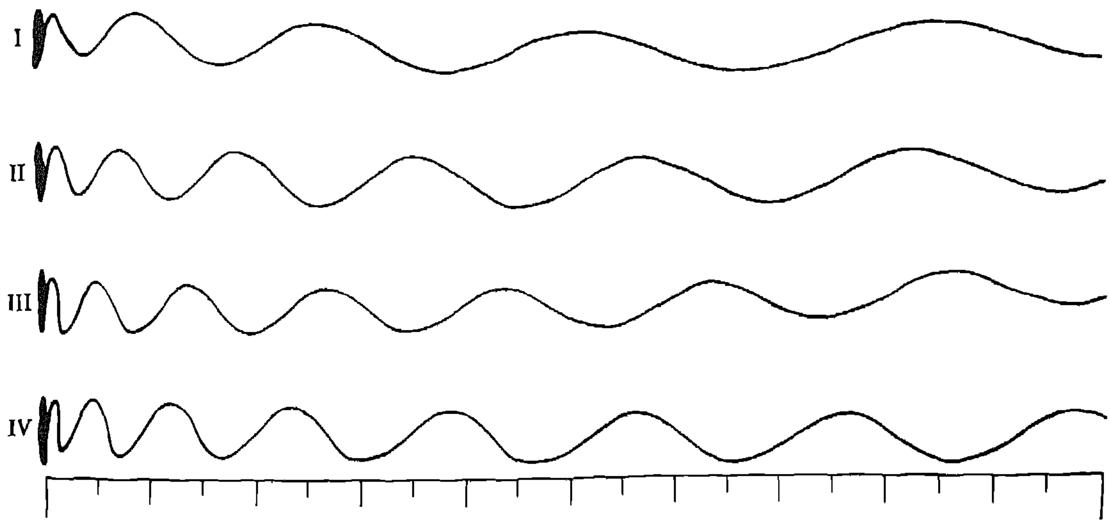


Fig. 5.15

Weight on the pan = 5 g

Observation	Mass in g	No of cycles	Distance within each cycle in cm	Time-period of the pendulum in s	Velocity in cm/s
I	Mass of the trolley and Pendulum =900	1 2 3 4	8.5 17.5 25.7 33.5	0.55	15.4 31.8 46.7 61.0
II	Mass of the trolley and pendulum + 500=1,400	1 2 3 4	5 6 11.2 16.7 21.6	0 55	10.5 20.4 30.4 39.3
III	Mass of the trolley and pendulum + 1,000 = 1,900	1 2 3 4	5.5 10 8 14 9 18.2	0 55	10.5 19.6 27.1 33.8
IV	Mass of the trolley and pendulum + 1,500 =2,400	1 2 3 4 5	4.7 9.0 13.2 16.4 18.5	0.55	8.5 16 4 24.0 29.8 33.6

Plot a time-velocity graph (figure 5.16). Calculate acceleration for each set observations.

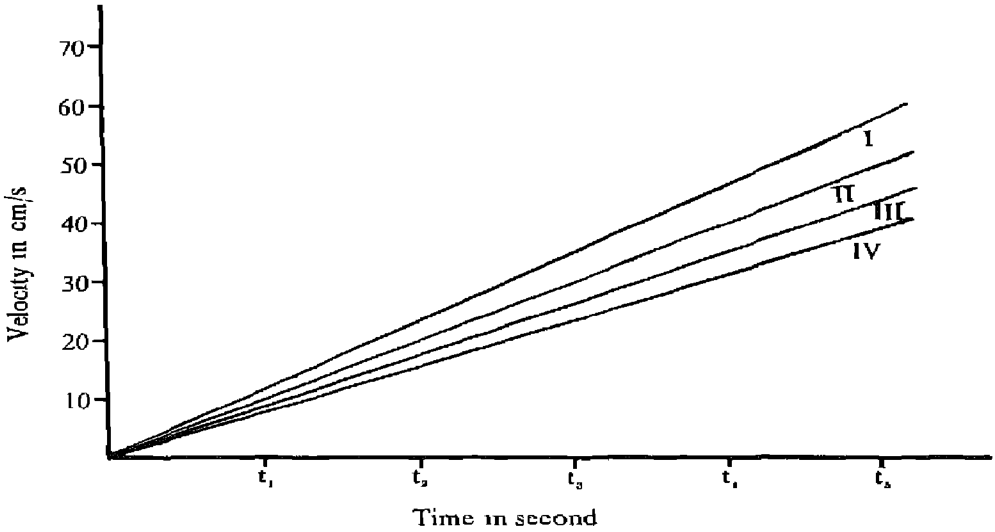


Fig. 5.16

(2) Do the same experiment with a trolley and a water-timer. Place a convenient weight (say, 24 g) on the pan of weight 10 g and find the acceleration of the trolley as before. Keeping the weight on the pan same, place a 100 g weight on the trolley. The mass of the moving body will now be given by the mass of the trolley plus 100 g placed on it. Find the acceleration in this case. What do you find ? Has the acceleration increased or decreased ? Repeat the experiment by keeping 200 g and then 300 g on the trolley and find the acceleration in each case. Do you get the same result each time ?

In a typical experiment following observations were recorded.

$$\text{Force} = (10 + 24)\text{g} = 34\text{g}$$

No. of observation	Mass = Total wt. =(Trolley and water-timer+added weight) in g	Distance of the drops from the starting point O in cm	Distance between two consecutive drops in cm	Time interval between two drops in s	Velocity=distance between consecutive drops in cm/s
I	650 + 100 =750	8.3 19.4 33.5 51.1	8.3 11.1 14.1 17.6	0.7	11.8 15.9 20.2 25.1
II	650 + 200 =850	9.7 22.0 37.0 54.5	9.7 12.3 15.0 17.5	0.7	13.9 17.5 21.4 25.0
III	650 + 300 =950	6.8 16.7 37.9 41.4 61.0	6.8 9.9 11.2 13.5 20.0	0.7	9.3 12.7 16.0 19.3 22.5

From the above reading draw a time-velocity graph shown in figure 5.17 and calculate the acceleration for each set of observations. For convenience, in figure 5.17 distance has been measured from the third drop. In actual measurements for different masses, the following values of acceleration were obtained.

No. of observation	Mass(m)=(weight of trolley + added weight) in g	$\frac{1}{m}$	Acceleration in cm/s^2
1	900	1.1×10^{-3}	27.5
2	1400	0.7×10^{-3}	18.2
3	1900	0.5×10^{-3}	14.3
4	2400	0.41×10^{-3}	11.9

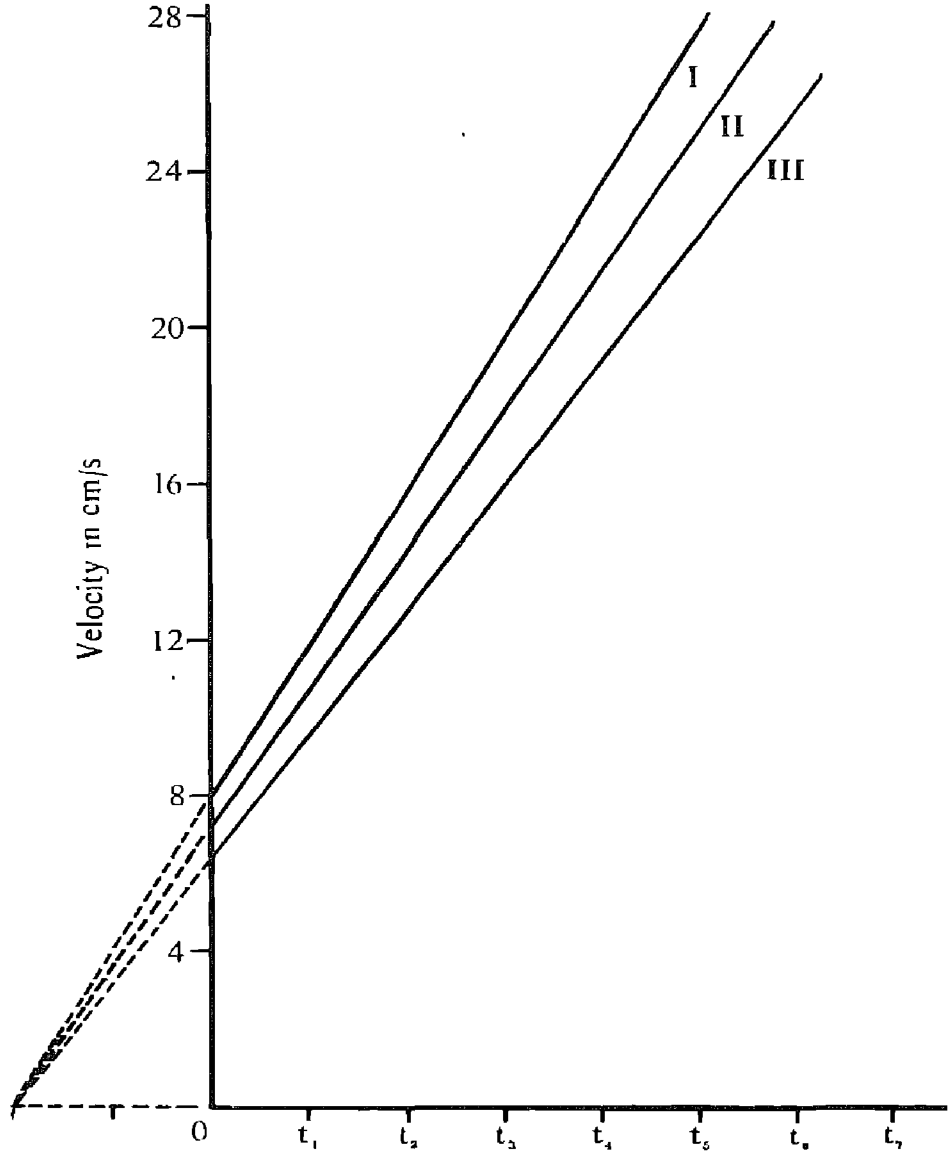


Fig. 5.17

Plot a graph taking acceleration along Y-axis and $\frac{1}{m}$ along X-axis. You will get a straight line

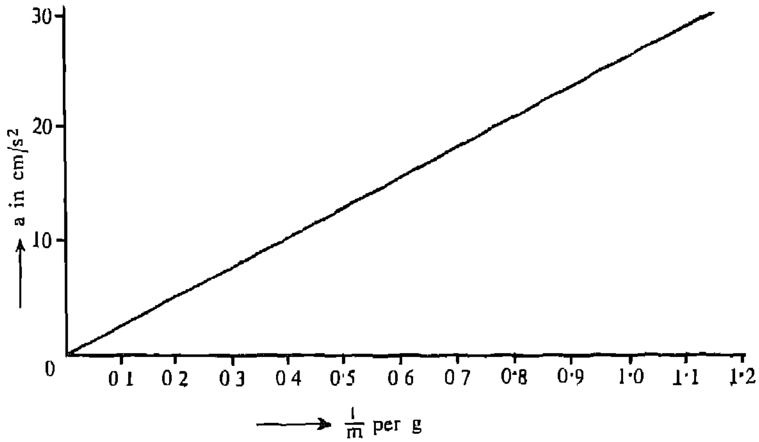


Fig. 5.18

inclined to the X-axis as shown in figure 5.18. The graph indicates that with the same force acting on a body, its acceleration increases with the increase in its value of $\frac{1}{m}$ i.e. decrease in its mass or vice versa. That is with the same force acting, the acceleration developed in a body is inversely proportional to its mass.

You find from the above experiments that the acceleration of a moving body is proportional to the force acting on the body and inversely proportional to its mass.

Now a is proportional to F and to $\frac{1}{m}$

Therefore a is proportional to $\frac{F}{m}$

Or $F \propto m\ a$

$= K\ m\ a$

Where K is a constant

In MKS system of units, $K = 1$

Therefore $F = m\ a$

You have already learnt that acceleration is measured in m/s^2. What are the units of m and F ? The unit of force is called *newton* (N) and that of mass is called *kilogram* (kg). You may define that one newton is that force which produces an acceleration of 1 m/s^2 on a mass of 1 kg.

Activity.

Take a trolley and find out its mass with a balance. Keep the trolley on the table. Tie one end of a thread to it and pass the other end over the pulley. Attach a pan to this end. Place a suitable weight on the pan and note down the acceleration. In one typical experiment the acceleration was found to be 0.064 m/s^2. The mass of the trolley was 0.65 kg. A heavy stone was placed on the trolley and the experiment was repeated. In the experiment the acceleration was found to be equal to 0 051 m/s^2. Using the above relation, you will get

$$F = (\text{mass of trolley}) \times 0.064\ m/s^2$$
$$= 0.65 \times 0.064$$
$$= 0\ 0416\ N$$

$$F = (\text{mass of trolley} + \text{mass of the stone}) \times 0.051\ m/s^2$$

$$0.0416 = (\text{mass of trolley} + \text{mass the of stone}) \times 0.051\ m/s^2$$

$$\text{or } 0.815 = \text{mass of trolley} + \text{mass of the stone}$$
$$= 0.65 + \text{mass of the stone}$$

Mass of the stone = 0.815—0.65 = 0.165 kg.

You can thus find the mass of any body by such an experiment.

Questions.

(1) A net force of 10 N gives an object a constant acceleration of 4 m/s^2. What is the mass of the object ?

(2) An object weighing 2 kg. is moved across a floor with an initial speed of 10 m/s. If it comes to rest in 5 seconds,

(a) what is the acceleration ?

(b) what is the force producing this acceleration ?

(3) An electron is accelerated by $10^7 m/s/s$ by an electric force of 10^{-24}N. Find the mass of the electron.

5.6. Intertial and Gravitational Mass.

(1) Take two trolleys A and B and a water-timer filled with coloured water. Tie a thread to A and pass the thread over a pulley fixed at the end of the table. Attach a pan to the other end of this thread. Add a few weights on the pan till the trolley begins to move. Record the drops on a sheet of paper placed below the trolley. From this find the acceleration. Now take trolley B and repeat the experiment with the same weights as were put on the pan of trolley A. Find the acceleration again. Let the accelerations in two cases be a_1 and a_2 respectively. Find the ratio of a_1/a_2. Now increase the force by increasing the weights on the pan of trolley A and B by the same amount. Let the accelerations be a'_1 and a'_2 Find the ratio of a'_1/a'_2 again. What do you find ? You will find that whatever be the force, ratios of a_1/a_2 and a'_1/a'_2 are always the same. From this you can say that if the same force causes same acceleration on two or more bodies, they have got identical inertia. For bodies with different inertia, the body which gains larger acceleration has smaller inertia.

So, you can put it in the following way :

$$\frac{\text{Mass of A}}{\text{Mass of B}} = \frac{\text{Inertia of A}}{\text{Inertia of B}} = \frac{a_2}{a_1} = \frac{a'_2}{a'_1}$$

(2) Now suspend the two trolleys separately by a spring balance and note the extension, which in turn gives the gravitational forces acting on the trolleys. Let the pulls in the balance be F_1 and F_2.

Then

$$\frac{\text{Mass of A}}{\text{Mass of B}} = \frac{F_1}{F_2}$$

In the former experiment you obtain the mass of the body through its intertial property, whereas in the latter you determine mass through the pull of the earth or gravitational pull. Sometimes the mass determined by the first method is called the inertial mass, whereas the mass determined from the earth's pull is called the gravitational mass.

Although these two terms seem to be indentical, yet the concepts behind them are quite different.

5.7 Mass, Gravitation And Weight

You know that earth's pull on a body is proportional to the mass of the body. This is why 100 g produces certain extension in the spring whereas 200 g produces twice as much extension. If you define the pull of the earth on a body of mass m as W then you will find that W depends on m.

You also know from Newton's law that this force W can create in a body of mass m an acceleration g such that

W depends on g

Combining these two relationships you will get

$W = Kmg$

$K = 1$ if you measure W in newtons, m in kg and g in m/s^2. You thus find that the earth's pull on the

body of mass m is equal to mg where g is the acceleration.

You therefore, understand why all objects, heavy or light, fall with constant acceleration. *The acceleration produced by the earth's pull at the surface of the earth is called acceleration due to gravity.* It is denoted by 'g' and is same for all bodies. Its value is about 9.8 m/s^2.

If W be the force of gravity, that is, the weight of the body of mass m, then according to Newton's law

$$W = mg$$

The force acting on a mass of 1 kg is given by

$$\begin{aligned} W &= 1 \text{ kg} \times 9.8 \text{ m/s}^2 \\ &= 9\ 8 \text{ kg m/s}^2 \\ &= 9.8 \text{ N}. \end{aligned}$$

This means that the force acting on every kilogram at the earth's surface is 9.8 N.

This relation, weight = mass × acceleration is also significant. This combines the two fundamental properties of matter namely, gravitation and inertia. From the above relation you find that when the mass of a body is doubled, the weight of the body W is also doubled. So, although gravitation and inertia are two different concepts of matter, yet they are closely related.

Weight is a measure of the gravitational force on an object. It is a force just like any other force, but it always acts vertically downwards towards the centre of the earth.

Mass is a measure of the inertial resistance of the same object to the changes in motion.

Question

Find out which is the correct statement :
An astronaut orbiting round the earth in a space-ship has (i) his weight zero and (ii) his mass zero.

5.8. Determination of g.

It is possible to determine the value of g by an experiment described in figure 5.7. Determine the time of oscillation of the wooden bar by measuring the time for 20 oscillations. Let the periodic time be T s. Let the marble hit the stick at S cm below the level where it was tied down. One complete oscillation of the stick involves the swing of the stick from C to D to E back to D and then to C. It is easy to see that the time required for the stick to move from C to D will be T/4. In that time, the marble falls through a distance of S cm. Since the marble starts from rest and moves under gravity a distance of S cm in T/4 s, you have

$$S = ut + \tfrac{1}{2} g t^2$$
$$= \tfrac{1}{2} g (T/4)^2$$
$$g = \left(\frac{32S}{T^2}\right)$$

In one typical example S was 78 cm and T was 1.6 s. From these data it is seen that

$$g = \left(\frac{32S}{T^2}\right)$$
$$= \frac{32 \times 78}{2.56} \text{ cm/s}^2 = 975 \text{ cm/s}^2.$$

6 TURNING EFFECT OF A FORCE : BALANCE : DENSITY.

6.1 Rotatory Motion

You have seen before that there is an intimate relation between force and motion. Force can start or stop motion. Force can even change motion. When a block of wood placed on a table is pushed, it moves forward in a straight line in the direction of the push. By pushing the block in the opposite direction, it can be moved in the opposite direction. Such a motion is called *translatory motion.*

Take a wooden or a cardboard disc and fix it with a nail on a smooth wooden block. Place the wooden block on the table. Hold the block tight with your hand as shown in figure 6.1 and push the disc.

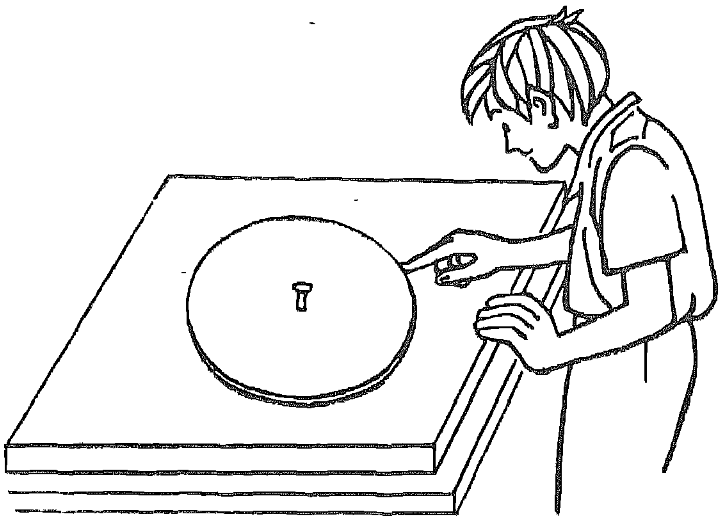


Fig. 6.1

What do you find ? The disc begins to rotate about the nail, which is its axis of rotation. Does the disc move as a whole ? You will find that the point where it is fixed on the wooden block does not move. This motion is called a *rotatory motion.* Here

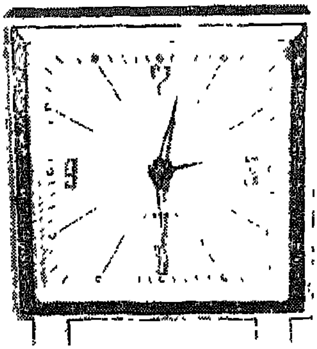


Fig 6.2

also by changing the direction of force you can change the direction of rotation.

6.2 Clockwise and Anti-clockwise Motion

Most of you have seen a clock (figure 6.2). Observe it carefully. You will find that the minute hand of the clock rotates through one complete revolution in 1 hour. This direction of rotation is called the *clockwise* rotation.

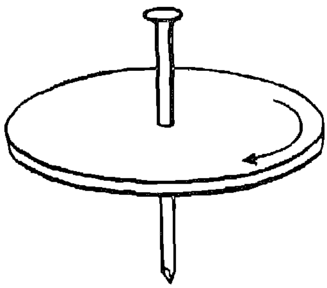


Fig 6.3

Take a wooden or a cardboard disc and pass a nail through its centre so that the disc can rotate freely about this nail. Hold the nail at the centre in your hand and push the disc along the arrow as shown in figure 6.3. What do you observe ? The disc will start rotating. If you compare the rotation of the disc with that of the minute hand of a clock, can you say that this rotation is also clockwise ? Can you make the disc rotate the other way round ? How will you apply the force to make it rotate *anti-clockwise ?*

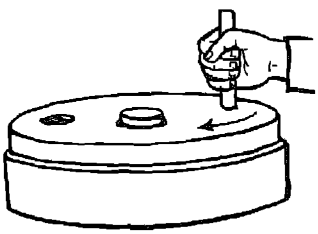


Fig. 6.4

Have you seen a grinding wheel (figure 6.4) ? The wheel is fixed at the centre and with the help of a peg fixed near the circumference you can make it rotate about an axis passing through the centre. Normally, grinding wheel is rotated in the clockwise direction. Can you explain why the peg is fixed near the circumference of the wheel ? What would have happened if the peg had been fixed near the centre ?

Questions

(*1*) *Support your bicycle on the stand and turn the paddle. The back wheel moves. Is the wheel having translatory or rotatory motion ? What is the axis about which it rotates ?*

(*2*) *When you ride a bicycle you paddle, the bicycle moves. Is the motion of the bicycle translatory or rotatory ?*

(3) Give few more common examples of rotatory motion.

6.3 Moment of a Force

Look at a door. The door has a knob to open it. Where is this knob fixed? Look at other doors. What do you find? Is the knob in every case fixed, as much away as possible from the hinges, about which the door rotates? When you open the door holding the knob in your hand, you apply a pull or a push. The door then rotates about the fixed edge. If the knob were fixed at the centre could you open the door by pulling the knob so easily? Would you require the same pull as you required when the knob was at the other extremity? You can do the following experiment:

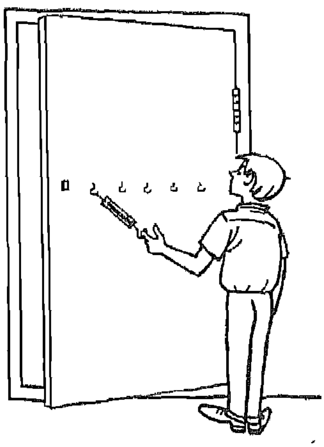


Fig. 6 5

To the door of your class room, fix hooks at various distances from the hinge as shown in figure 6.5. Take a spring balance, attach it at the hooks in turn and find the magnitude of the pull required to open the door for various positions of the hooks. Enter your observations in the following table.

No. of observation	Distance of the hooks from the hinge	Force required at the hook to open the door

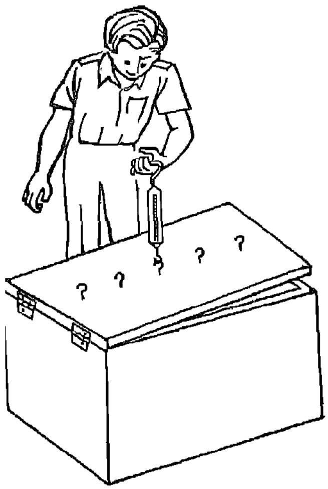


Fig. 6 6

Activity

Take a box fixed with a lid as shown in figure 6.6. The lid rotates about the hinges. Fix hooks at various places as shown. Attach a spring balance to these hooks in succession and try to open the lid. Note down your observations in the following tables :

No. of observation	Distance of the hooks from the hinge	Reading in the spring balance (Force required at the hooks) to open the lid

Determine from the above observations, which position of the spring balance gives you the minimum force required to open the lid ?

Go to the garden gate. This is also fixed at one end. Now try to open it. You will push the door at the farthest end. Try to open the door by giving push at various places from the fixed end. You see here also that if you want to rotate the door, you have

to apply smaller force at a larger distance away from the axis of rotation. In other words, it is much easier to rotate a body if the force is applied at the farthest end from the axis of rotation or the turning power of a force is much greater if the force is applied at the farthest end.

Questions

(1) Suppose you want to open a nut, say on your bicycle with a spanner (figure 6.7).

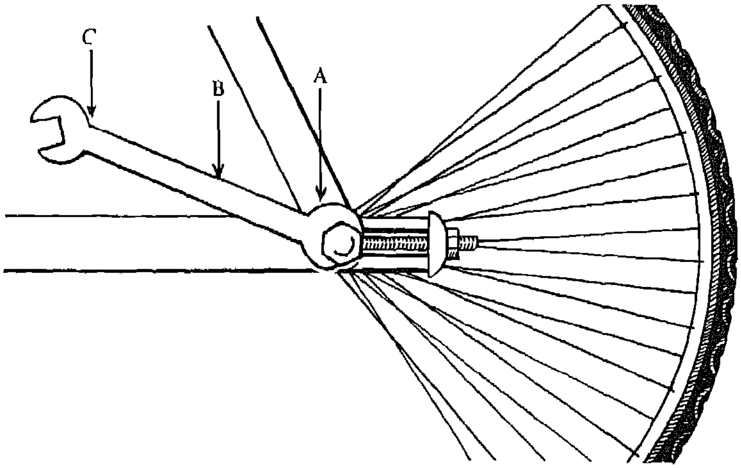


Fig 6.7

In which of the positions A, B and C of the spanner do you think you should apply force so that it is easiest to open the nut ?

(2) Your bicycle has a handle to turn it. Where do you hold the bicycle handle ? Why are the grips on the handle fixed at the ends ?

(3) Give few more examples to show that for rotating a body you apply force as much away from the axis of rotation as you can.

Activity

Take a rectangular wooden piece about half a metre long with a hole at one end and a disc magnet at the other end. Fix this wooden piece at one end on a stand as shown in figure 6.8.

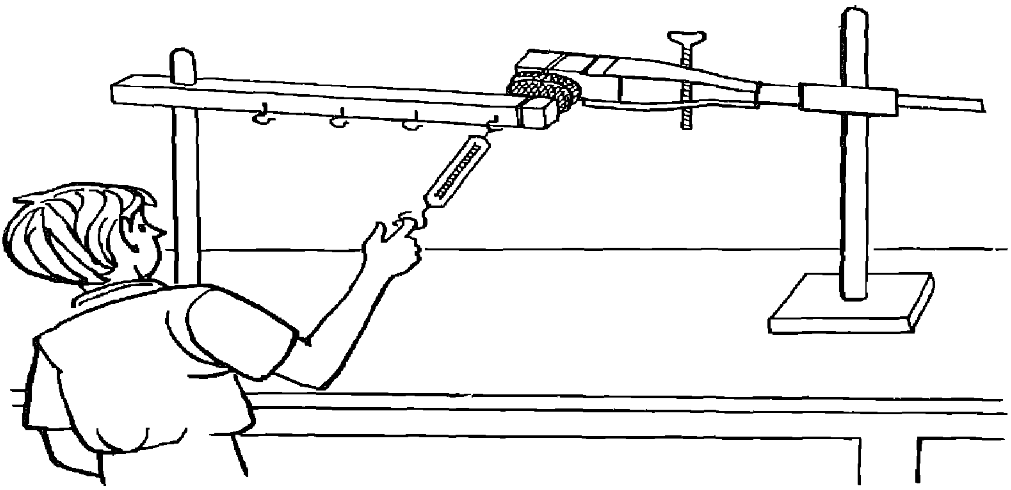


Fig 6.8

Fix another disc magnet on a rectangular block of wood and clamp it on a stand some 5 cm away so that the disc magnets attract each other. Fix small hooks at various places on the first wooden piece and attach a spring balance to these hooks in succession. Pull the spring balance till the magnets separate. Record your observations.

Distance of the hooks from the fixed end	Force applied (pull)					Pull × distance
	1st obs.	2nd obs.	3rd obs.	4th obs.	Average	

What inference do you draw from the above experiment ? Is it correct to say that the product of the force and distance is a constant ?

Activity

(1) Take a 30 cm Aluminium scale. Pass one end of this scale in a groove cut on a wooden block and fix this block in a clamp of a stand. Fix a disc magnet at the other end of this scale. Fix another disc magnet on a stand and bring it above the scale so that the two magnets attract each other. Attach a pan on the scale as shown in figure 6.9.

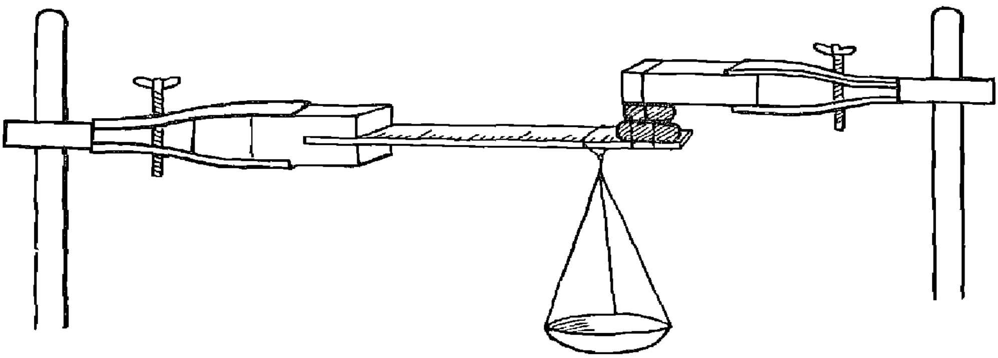


Fig. 6.9

Keeping the pan at different distances from the fixed end, put weights on the pan till the magnets separate. Record your readings in the following table

No. of observation	Distance of the pan from the fixed end	Weight on the pan	Distance × weight

(2) Repeat the above experiment, but instead of attaching a pan, use a spring balance and find the pull required to separate the magnets for different positions on the scale from the fixed end. Find the product of pull and distance for each case. What do you observe ? Is the product a constant ?

In the above experiments, you have seen that the product of force (weight) and distance is a constant. In all these cases the force (weight) applied was in a direction perpendicular to the beam. If however you have a force which acts in a different direction, will the turning effect of the same force be different ? To understand this do the following.

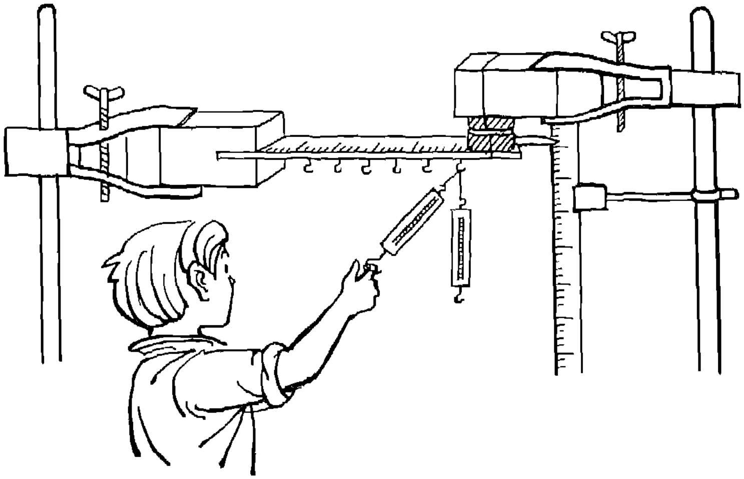


Fig. 6.10

Take a 30 cm wooden scale and fix it at one end as shown in figure 6.10. Fix a disc magnet at the other end. Fix another disc magnet on a stand some 5 cm away so that the two disc magnets attract each other. Because of attraction the scale bends and the pointer attached to the scale shows some reading. Fix small hooks at various places on the scale and

attach spring balance at one of these hooks. Pull the spring balance in the vertical direction tıll the readıng of the pointer is zero. Note down the reading on the spring balance. Now pull ın an inclined direction and find out the pull requıred to bring the pointer to zero. Do you get the same reading in both the cases ? If not, why not ? When ıs the pull required to bring the pointer to zero minımum ? You see that even if the same pull is applıed at a given distance from the fixed point the turning effect of the force is dependent on the dırection ın which it is applied. The turnıng effect of a force is maximum when the force is applied in a direction perpendıcular to the beam which rotates. Thus *the turning effect of a force depends upon the magnitude of the force, distance of the point of application of the force from the axis of rotation and the direction along which the force is applied.* The turning effect of a force is called the *moment of a force* and is defined as the product of the force and the perpendicular distance of the point of application of the force from the fixed axis (axis of rotation).

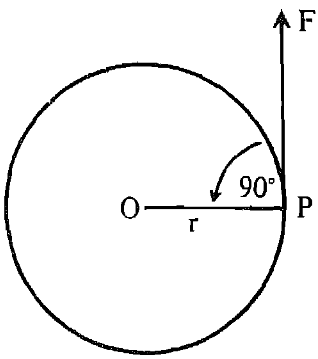


Fig. 6.11

Now see what it means. You have a disc fixed at a point O as shown in figure 6.11. If force F ıs applied at P along the direction as shown in the figure, the moment of the force is $F \times OP = F.r$

where F = Force applied

and r = OP = Perpendicular distance of the point of application of F from the axis of rotation.

Activity

Pull a bar at P with a force F along PS as shown in figure 6.12.

What is the moment of the force ? Is this moment $= F \times OS$?

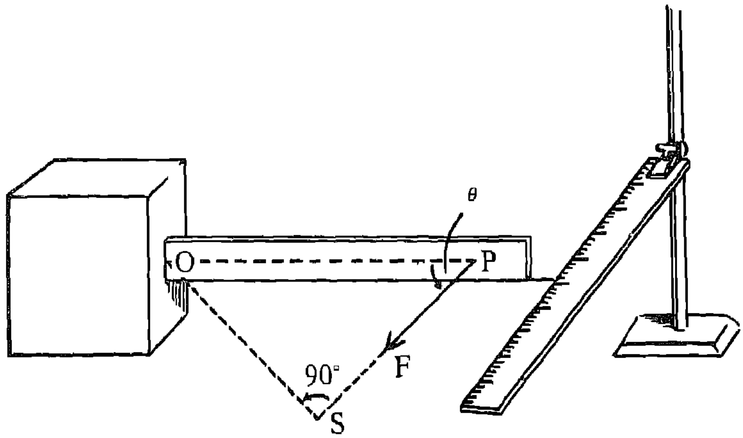


Fig. 6.12

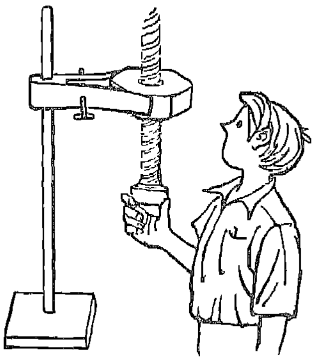


Fig. 6.13

6.4 Clockwise and anti-clockwise direction

Take a screw and a nut (figure 6.13). Fix the nut on a stand and rotate the screw in the clockwise direction. What do you find? The screw moves forward. Now rotate the screw in the reverse direction. The screw moves back. On a paper the direction of the clockwise motion is given by an arrow pointing downwards, whereas the direction of the anti-clockwise motion is given by an arrow pointing upwards as shown in figure 6.14. The clockwise moment is taken to be negative and anti-clockwise moment is taken to be positive.

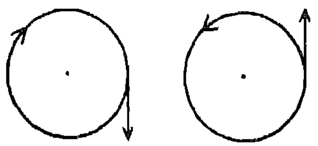


Fig 6.14

6.5 Principle of Moments Applied to Levers

Lever is simply a bar free to turn about some point of the bar. To understand how principle of moments can be applied to levers, do an experiment.

Take a half-metre scale and a wedge. Balance the scale on the wedge so that it remains horizontal.

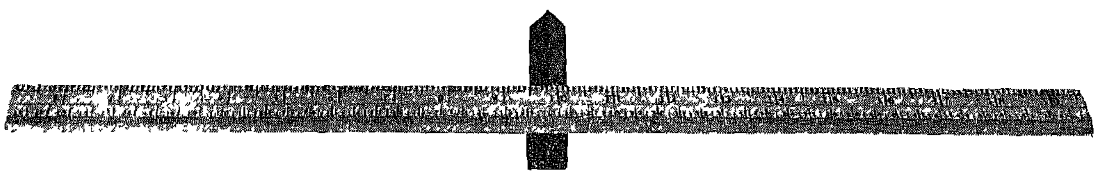


Fig. 6.15(a)

Note down the point where the scale balances [figure 6.15(a)]. This is called the fulcrum. Now take two 10 g weights and place one on each side of the fulcrum such that the scale remains horizontal again as shown in figure 6.15(b). Make sure that you do not change the fulcrum. Now find the distance of

Fig. 6 15(b)

these two equal weights on either side of the fulcrum. What do you find ? Are these distances equal ? What does this indicate ?

Now place 12 g weight at some distance from the fulcrum on one side of the scale [figure 6.15(c)].

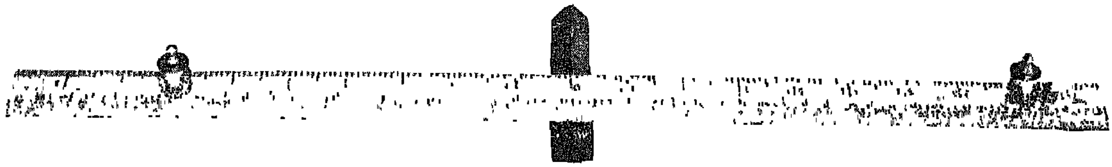


Fig. 6 15(c)

Balance the scale by taking one 10 g weight on the other side. Note the position of the weights on either side of the fulcrum. What do you find ? Are the distances from the fulcrum of the 10 g weight and the 12 g weight equal ? If not, what does this indicate ? Do you find that the product of the force (weight) and the distance of the weight from the fulcrum is equal for both sides of the fulcrum ? Can you then say that the product of force and distance is constant ?

Left hand side				Right hand side			
Weight placed	Position of the weight	Distance of the weight from the fulcrum	Weight × distance	Weight placed	Position of the weight	Distance of the weight from the fulcrum	Weight × distance

6.6 See-saw

Have you seen a see-saw in a park ? Two boys sit on the see-saw at the two ends of the plank as shown in figure 6.16. If the boy A gets off, what will

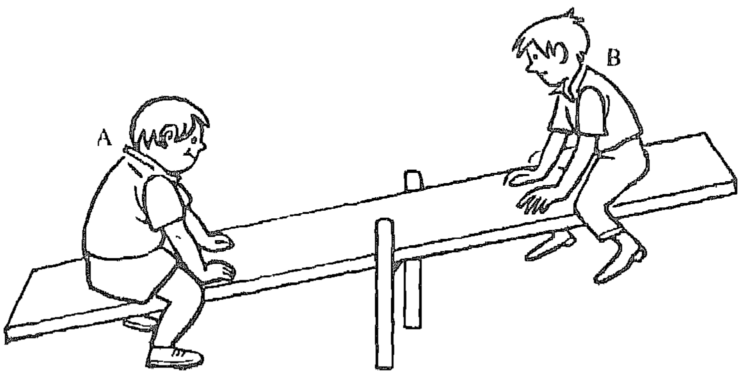


Fig. 6.16

be the position of the see-saw ? If then B gets off, what will be the position of the see-saw ? Now if one of the boys is heavier than the other will they be at the same distance from the fulcrum when the see-saw is balanced ?

Question

Suppose a boy whose weight is 20 kg sits 1 m away from the centre of a see-saw . If another boy whose weight is 15 kg wants to lift this boy, can he do it ? Where should he sit on the see-saw so that the heavier boy can be lifted ?

Activity

Take a metre scale and a wedge. Place the scale on the edge of the wedge at 50 cm mark so that the scale remains horizontal as shown in figure 6.15(a).

Now do the following :

(1) Place a weight of 100 g on one side of the scale. Place another 100 g on the other side and move it till the scale is horizontal. Note down the position of the weight on the scale.

(2) Place the 100 g weight at various positions, say 40 cm, 30 cm, 20 cm, 10 cm marks on one side of the scale and adjust the position of another 100 g weight on the other side so that the scale remains horizontal in each case. Note down the position of the second weight in each case.

(3) Place 100 g weight at a convenient mark, say 30 cm on one side of the scale and try to balance this weight by taking say 20, 30, 40, 50 g on the other side Note the position of the weights in each case. Can you balance this 100 g weight by a small weight

say 1 g ? Can you determine the minimum weight that you should use to obtain a balance ?

(4) Now instead of keeping the scale at 50 cm mark, shift it to say 40, 30, 20, 10 cm marks. Place a 100 g weight on the smaller side of the scale and move it till the beam becomes horizontal. Note down the position of the weight in each case. Now if instead of keeping the weight on the smaller side, you keep it on the other side, can you obtain a balance ? Would you require more weight or less to balance the scale when it is kept at 10 cm mark ?

(5) Repeat the above experiment by taking different weights, say 50, 40, 30, 20 g.

How can this principle be used in lifting heavy loads ? Right in the middle of a street there is a heavy load. You cannot possibly lift it, but you want to remove it so that the road is made clear. What will you do? Can you push it ? If not then how are you going to remove this load ? Will a long and strong beam of iron serve the purpose ? You will see that with a very small force*, you can lift this weight. For doing this put one end of a long and strong beam below the load and place a piece of wood or stone under the beam near the load. This wood or stone serves as the fulcrum against which you can press the beam and lift the load. This arrangement is called a *lever*.

Consider some examples of levers and see their usefulness in your daily life.

* The principle underlying the lever was first put forward by Archimedes, a renowned Greek scientist. He is said to have remarked "Give me a lever long enough and strong enough and a point on which to rest it and I will lift the whole earth"

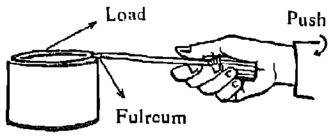


Fig 6.17

When you open the lid of a can with the help of a screw-driver as shown in figure 6.17 the screw driver here acts as a lever. The point where the screw-driver rests on the rim of the can is the fulcrum and the load (resistance offered by the lid) acts on the tip of the screw-driver while the push acts downwards on the handle. As the push arm is much larger than the load arm, a small push produces a large force at the point of contact with the lid so that the latter is forced open.

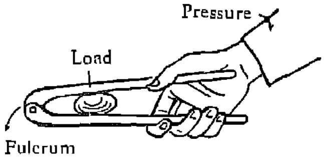


Fig. 6.18

Another familiar example is a nut-cracker. The hinge or the fulcrum is at one end and the pressure is applied at the other end. The nut—placed between the two—experiences a large force sufficient to crack it (figure 6.18). Other examples of levers are shown in figure 6.19.

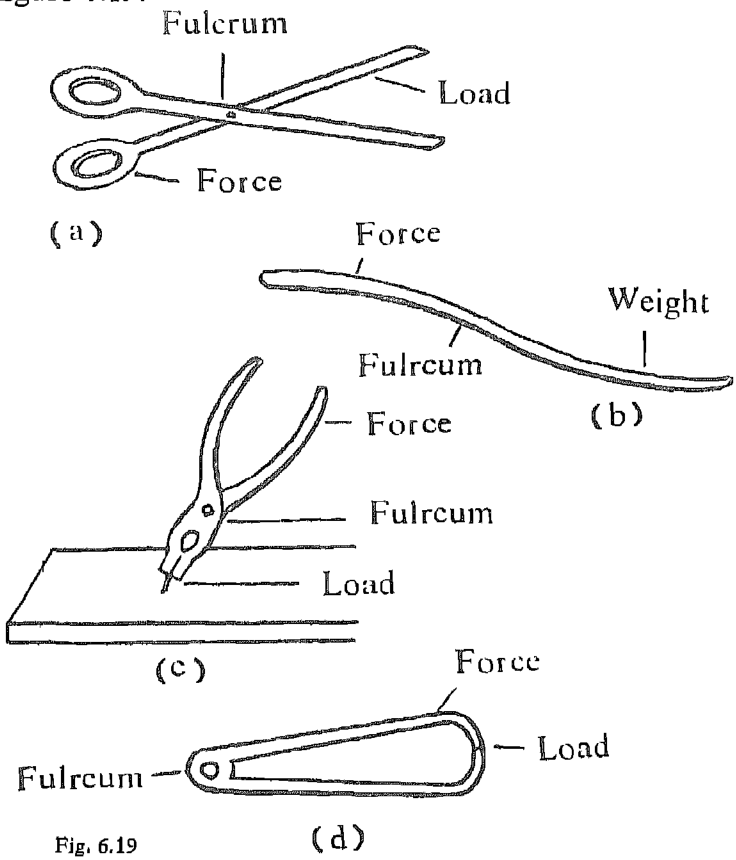


Fig. 6.19

6.7 Balance

Take a 30 cm aluminium scale having equidistant holes from the centre. Pivot it at the centre and attach two pans of equal weight at the two ends as shown in figure 6.20. The scale remains horizontal. If you put one gram weight on one of the pans, what happens to the beam ? Why does the beam tilt ? If you put the weight on the other pan, what happens ? If you put 100 g in both the pans what happens to the beam ? Why is the scale balanced in this case ? The weight on the right-hand pan tries to rotate the beam clockwise, whereas the weight on the other pan tries to rotate it in the anti-clockwise direction. The beam is balanced because the tendency to rotate it in the clockwise direction equals the tendency to rotate it in the anti-clockwise direction.

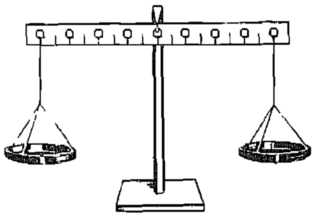


Fig 6.20

Moment of the force in clockwise direction
= Moment of the force in the anti-clockwise direction

Activity

(1) Take a balance which you have made and put a stone on one of the pans. Put sugar on the other pan till the beam is horizontal. Take this sugar out and put it in a beaker and call it A. Now instead of sugar put sand on the pan. Adjust the quantity of sand till the beam is again balanced. Take this off and put it in another beaker. Call it B. Repeat the experiment with pieces of wood, pin, chalk etc. and keep these in different beakers. Is there anything common with various materials such as sugar, sand, wood, pin, chalk, etc.

kept in different beakers ? They look different, their colours are different, their tastes are different, yet there is something common in them. What is common to all these substances ?

(2) Take a spring balance and attach a pan to it. On the pan put the stone which was kept on the pan of the balance. Mark the extension of the spring. Remove the stone and put sugar from beaker A on the pan of the spring balance. What do you expect to find ? Is the extension caused by the sugar the same as that caused by the stone ? You find that for each of these substances the extension produced in the spring is the same as you learnt earlier. This means that the mass of the stone is equal to the mass of the sugar in beaker A = mass of sand in beaker B = mass of wood-pieces in beaker C = etc. etc.

You know that if the pull of the earth on two bodies is the same, then their masses are also equal. You thus see that with a beam balance, one can determine the mass of a given body. You have already chosen a kilogram as a standard of mass and you compare the masses of all the bodies with that of a kilogram.

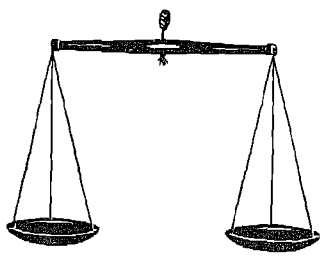
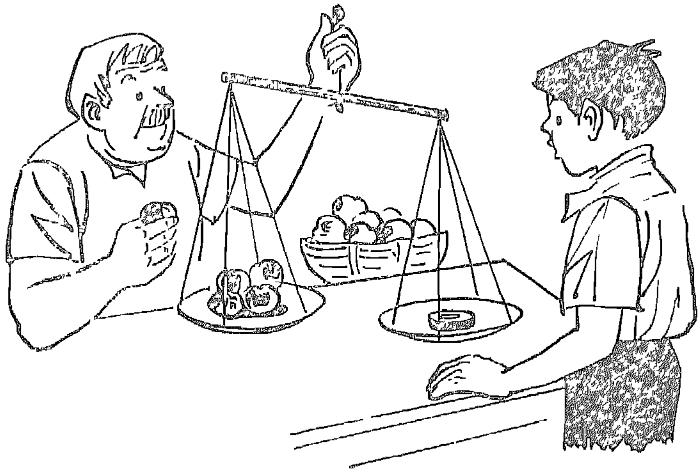


Fig. 6.21

Have you seen the balance used in a grocer's shop ? How does he measure the mass of an article ? He holds an 'instrument' in his hand which he calls a balance. It is nothing but a rod of wood (or metal) at the two ends of which are attached two pans by means of strings as shown in figure 6.21.

In the centre of the rod there is a hole and through this passes another stout string. You have seen that with the help of this balance the grocer compares the mass of an unknown body with a standard mass. What happens if the unknown body weighs a little more or less than the standard mass on the pan ? Will the beam still remain horizontal ?



6.8 Density

You already know how to measure the volumes of regular and irregular bodies. Now try to find the relationship between the mass and the volume of different bodies.

Activity

(1) Take a balance and put a glass marble on one of the pans. Put weights on the other pan till the beam is horizontal. You will get the mass of the marble. With the help of a measuring jar find out the volume of this marble. Take another marble and find its mass and volume. Repeat the process for 10 marbles of different sizes. Tabulate your results.

No. of observation	Mass of the marble	Volume of the marble	Ratio of mass/volume

From the above experiment you find that if you increase the volume of the marble, the mass of the marble also increases. But you find that the ratio of the mass of the marble to its volume is constant.

(2) Take a beaker and place it on one of the pans. Find out its mass. Add 10 ml of

water to the beaker and determine the mass of 10 ml of water. Put different amounts of water in the beaker and find out the corresponding masses. Tabulate your results.

No. of observation	Volume of water in ml	Mass of water	Ratio of mass/volume
	10		
	20		
	30		
	...		
	...		
	...		
	.		
	.		
	...		
	...		
	...		
	.		
	100		

(3) Take some wooden cubes from your kit. Find out the masses of the cubes and their respective volumes. Tabulate your results.

No. of observation	No of cubes	Volume of the cubes	Mass of the cubes	Ratio of mass/volume

(4) Take 25 pins and find out the mass of these 25 pins. Determine the volume of these pins. Take another 25 pins and find out the mass of 50 pins. Determine the volume of these 50 pins. Repeat the process with 75, 100 pins etc. and tabulate your results.

No of observation	No. of pins	Volume of the pins	Mass of the pins	Ratio of mass/volume

From these experiments you find that in each of these cases the ratio of mass of the body to its volume is a constant quantity. The ratio of the mass of a body to its volume is called the *density* of the body. You measure mass in kilogram and volume in cubic metre. Therefore you will express density in kilogram/cubic metre or kg/m^3.

Activity

(1) Take a beaker containing water. Drop a glass marble. What do you find ? Does the marble sink ? Put a few pins. What do you find ? Put a wooden cube on the surface of water. What do you find ? Does it also sink ? Can you draw any inference about which bodies will float and which bodies will sink ?

(2) Find out the density of stone, sand, charcoal, plastic etc., and verify that those bodies which have their densities less than the density of water will float on water, whereas those which have higher densities than the density of water will sink in it.

(3) Determine the density of til (sesame) oil. Find out which of the substances of (1) and (2) will float on til oil and which of the substances will sink in it.

7 STRUCTURE OF MATTER

7.1. Introduction

You see around you a number of things, living and non-living, of all sorts, of all shapes and sizes. Each varies from the other in colour, odour, texture, hardness, weight and other properties. The milk you drink is white and liquid, the toothpaste is sticky and has a smell. Your shirt is made of cotton, your shoes are of leather. Your house is made of bricks, the streets have tar on the surface. You can notice and put down in writing all the major properties of everything around you. All these objects are different forms of matter. Any particular kind of matter is called a *substance*.

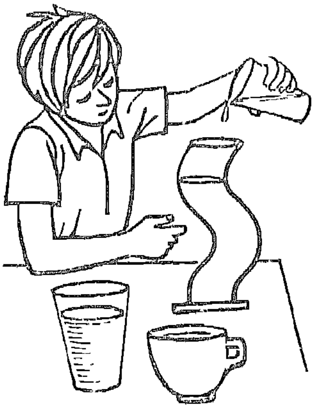


Fig. 7.1

Activity

Name 10 different substances that you find in your home. How many of them are also found in your friend's house and in your school? List five new substances, if any, you find in your school.

7.2. Classification—Three States of Matter.

Examine some common substances that you find around you and see how they can be grouped in respect of some 'like' and 'unlike' properties and behaviours.

Fig 7.2

Take some water in a drinking glass. The water has now the shape of the glass. Pour a part of it in a cup. It takes the shape of the cup. Pour some water in a bent tube and watch the shape of the water now (figure 7.1). Do you find a *free surface* of water in each of the vessels ? Now, tilt the glass containing water (figure 7.2). Is the surface of water

still horizontal ? Can a small cup of water fill the glass ? Does it mean that although water has no shape of its own, yet it has a free surface and a *definite volume ?*

Question.

Take three rectangular boxes of different sizes and pour the same amount of water successively in each of them. Find the volume in each case by measuring the length, breadth and height of the liquid in the container. Are the values of volumes so obtained identical or nearly so ?

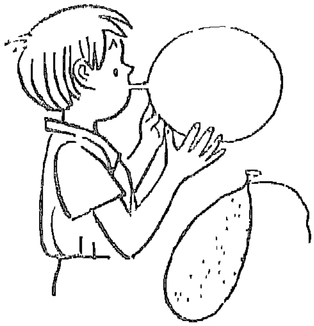


Fig 7.3

Pour water on the floor and observe that it *flows* along a surface sloping downward. Do substances like milk and oil show similar properties, that is, do they behave in the same manner as water ?

Blow air from your mouth into a number of toy balloons of different shapes and sizes (figure 7.3). Does air occupy the volume and shape of each of these balloons ? Now keeping the mouth of a balloon closed, separate the air inside by pressing the balloon into two parts (figure 7.4). Join the mouth of an empty balloon to this inflated balloon. Does air *flow* into the empty balloon and fill it completely, even if its capacity is bigger than that of the inflated balloon ? Do you hear a 'hissing sound' when air comes out through the mouth of a fully inflated ballon or a foot-ball ? Have you noted that a loud sound is produced when the tyre of a motor car or a lorry bursts ?

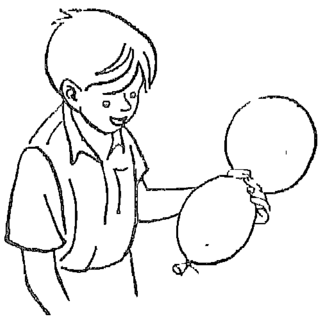


Fig 7 4

From these simple experiments and observations, you have found that both air and water can *flow*. They have *no shape* of their own. These substances are called *fluids*, as they possess the property of fluidity, i.e. flowing. Fluids can be further classified

as *liquids* and *gases* based on some properties in which they differ. Water, milk, oil etc. are liquids. Air, oxygen, hydrogen etc are gases. Liquids have no shape of their own but liquids can flow. Liquids, however, have got definite volumes and maintain a free surface which is horizontal. Gas has neither shape nor size and a gas completely fills the space in which it is put. Gas has, therefore, no free surface of its own and no fixed volume.

Examine other substances like wood, metal, salt, sugar, etc. A piece of wood, a pencil, or a marble has got its own peculiar shape and size. You can place it in a glass, on the table or hold it in your hand. It retains its shapes and sizes no matter where you put it and requires no container to maintain its size and shape.

These substances cannot flow like fluids. They possess definite shapes and sizes and are called *solids*. They offer resistance to force trying to deform their shape or size.

From the above analysis, you find that matter can be classified into (1) solids and (2) fluids. Fluids are further sub-divided into (i) liquids and (ii) gases. The classification of matter into these three categories, namely, solids, liquids and gases is done by taking into consideration certain distinguishing characteristics.

Questions

1. *Fill in the following gaps :—*

(*i.*) *A solid has got a definite .. and... . ...*

(*ii.*) *A liquid has got a definite.... .. but no........*

(*iii.*) *A gas has neither.. .....nor. ......of its own.*

(*iv.*) *A solid may be held by a horizontal . but a liquid requires both. ..... and . .....supports of a cantainer.*

(*v.*) *A liquid has got a free. .... which is ...., but a gas has got no such....... surface.*

(vi) A solid cannot...... .but a fluid can.... ....

(vii.) Matter can exist in.... ..different ....

2. Name a few properties which are common to solid, liquld and gas.

3. What distinguishes - (i) a solid from a liquid, and (ii) a liquid from a gas ?

7.3. Inter-conversion of states of matter.

You know now that there are three states of matter. Is this classification permanent ? Is inter-conversion from one state to another possible ? You can think of any object or substance and you will find that it is either a solid, a liquid or a gas. Most of the objects in your room are in the solid state. Water and milk are liquids. The air you breathe is a gas. Of course there are a few substances on the borderline, like pitch or coaltar which is in a semi-solid state. Take some water. When it is boiled, it becomes steam, which is in a gaseous state. What is ice ? Is it not solidified water ? Have you seen how ice-cream is prepared ? You can try the following experiment to freeze water into ice.

Fig. 7.5

Take a test tube half filled with water. Put sufficient quantity of pounded ice in a glass. Mix some common salt with the ice. Dip the test tube containing water inside the mixture (figure 7.5). After some time the water in the tube will freeze. Ice mixed with common salt is commonly known as *freezing mixture*.

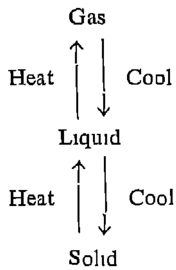
You have also seen that when ice melts, it becomes water. Steam or water vapour can be condensed into the liquid—water. Hold a spoon or a wooden rod over steam given off from boiling water. After a while remove the spoon or the rod from the steam. Do you find water drops on the spoon or the rod ? Water drops formed under the lid of a

pot of boiling water are nothing but condensed steam. Try the following experiment.

Take a glass (figure 7.6) Put a few pieces of ice in it. Wait for some time. Do you find the outer surface of the glass moist ? Wipe out the moisture. Wait for some time. Do you find moisture reapearing on the outer surface of the glass ? Where does it come from ? This shows that air contains water in the form of vapour. When it comes in contact with the cold surface of the glass, the water-vapour condenses into liquid water.

Fig 7.6

You can, therefore, understand that in the liquid state you call a particular substance 'water'. The same substance in the solid state is known as 'ice' and in the gaseous state as 'water-vapour' or 'steam'. You thus see that these states are inter-convertible, that is, one state can be changed into the other by giving heat to, or removing heat from, the substance. For water, the liquid state is the natural state at room temperature. Similarly for iron, sulphur, etc., solid state is the natural one at room temperature. But these substances can also be converted into liquid form at high temperatures. They can be changed into vapour at still higher temperatures. Take a small quantity of finely ground yellow sulphur in a test tube. Heat it gently until it melts. Continue heating until some of it changes to sulphur vapour appearing above the liquid. Now let the test tube cool. The vapour and the liquid will again be converted to solid sulphur showing that sulphur has merely changed its form due to heating or cooling.



Question

Make a list of ten substances of which three are liquid and three are gas at room temperature.

You have observed that during change of state, no new substance is produced. Water, whether it is in the solid (ice) or gaseous (steam) state, is still water with the same chemical composition (consisting of two atoms of hydrogen and one atom of oxygen). Sulphur, paraffin wax (candle), and other substances can be changed from solid to liquid and back to the solid state without any change of their respective chemical properties. So, you find that the classification of matter based on its physical states does not answer our questions : Is there any thing common to all kinds of matter ? Is there any unit or 'building brick' of which matter is composed ? What is the structure of matter ?

7.4. Granular structure of matter.

In fact, the above questions are not at all new. The ancient Greek philosophers* (some 2500 years ago) had pondered over these question regarding the structure of matter. They argued like this : Matter appears in bulk and is continuous. But is it really so ? Suppose a piece of stone is broken into two

---

* The first atomic theory of matter was introduced by the Greek philosopher, Leucippus (500 B.C.) and his pupil, Democritus (460 B C.), Aristotle (384-322 B.C.) and Epicurus (341-270 B C) discussed the atomic ideas of matter in detail and it is to these men that we owe most of our knowledge of ancient atomism.

Aristotle developed a theory of matter as a part of his grand scheme of the universe. He thought that there were four basic substances—'elements'—earth, air, fire and water and four qualities—cold, hot, moist and dry Each element was characterised by two qualities. Thus the element,

(*Continued in next page*)

parts, then these parts are broken again and so on. How far can this go ? Can one go on breaking it indefinitely ? They believed that by continuing the break-up process, they would eventually come down to the smallest particle which cannot be further subdivided. They called that particle 'atom' from the Greek word 'atomos', meaning unbreakable or indivisible. They also suspected that atoms are in constant motion. See whether you can have a few common examples and can do some simple experiments showing the granular structure of matter.

7.5. Some evidence regarding granular structure of matter.

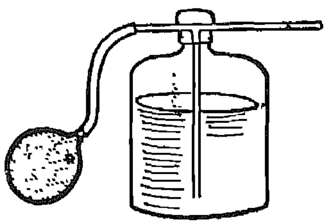
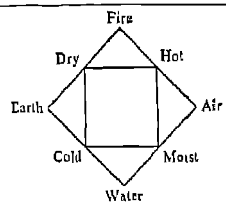


Fig. 7.7

You have seen a sprayer, (figure 7.7) which can resolve a liquid into minute drops. This is used to paint motor cars, steel almirahs and furniture, even to spray water on your head after hair cut in a saloon. A quantity of liquid which appears in bulk can be broken up into minute particles.

A grain of salt, sugar, or sand can be broken up into powder. Talcum or baby powder appears very smooth, but if you examine it closely under a magnifying glass, you find its grain-like structure.

Earth is dry and cold
Water is cold and moist
Air is moist and hot
Fire is hot and dry



It may be mentioned here that the Hindu philosopher, Kanad, conceived five basic substances पञ्च तन्मात्र (Panch Tanmatra), namely क्षिति (earth), अप (water), तेज (fire), मरूत (air), व्योम (akash or space), out of which the physical world was built.

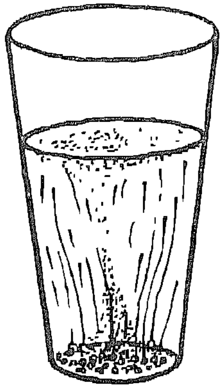


Fig 7.8

Put a few crystals of potassium permanganate in water in a glass (figure 7.8). Observe how a coloured streak is formed. Where have the crystals gone? Now take 1 cc of this coloured water and put it in a beaker containing 100 cc of clean water. Compare the colour in the new solution with the colour in the first solution. If you go on diluting the solution in this way, the colour of the solution becomes fainter and fainter. But does it not still contain few particles of the crystals? Does it suggest that a tiny crystal of a substance like potassium permanganate can be broken up into very very small particles, too small to be seen and even then these particles retain the properties of the respective substances?

A substance like 'quinine' (which has a very bitter taste) can be detected even when 1 part is present in 15,000,000 parts of water. What does it suggest? The obvious explanation is that the substance when dissolved in water breaks up into very very small particles, too small to be seen. But each particle retains its property which is proved by taste.

You might have observed how the odour of camphor, naphthalene or any scent spreads in the room. The naphthalene balls put under silk or woolen clothes to protect them from attack of insects disappear in course of time. How does it happen? Does it suggest that the particles of camphor or naphthalene are carried by air from one place to other? Does it also suggest that air (which is a mixture of gases) consists of minute particles?

If you put some water in a dish, it is found to disappear after some time. Water leaves the surface in the form of tiny particles too small to be visible. Wet clothes get dried up in this way. Water

leaves from the surface of rivers, oceans, lakes in the form of minute invisible particles. The same particles of water thereafter combine to form rain, fog and mist. All these show the granular nature of water, although when seen in bulk, it appears continuous.

You may try the following experiment. Take a jar and fill half of it with water. Now put a few drops of cooking oil in it. The oil being lighter than water will float on the water surface. You will see two separate layers of oil and water (figure 7.9). Now shake the vessel thoroughly. The oil is found to be broken into minute globules and mixed with water. If you allow the mixture to stand for some time, the tiny oil globules combine again and rise to the top to form a separate layer. This breaking up and re-combination of the oil and its mixing with water show that oil must be consisting of tiny particles. You can similarly show that water is also made of tiny particles.

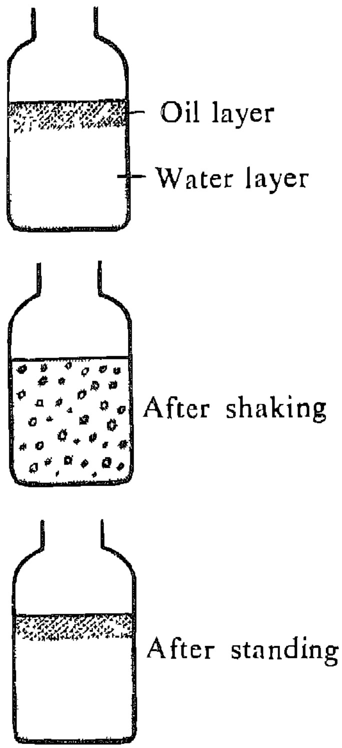


Fig. 7.9

If you pour a few drops of kerosene oil or oleic acid (which is even better) on water, it covers the water surface as a thin coloured film. If a few drops of this mixture are poured on a large water surface, the presence of oil (or oleic acid) is evident from the colour of its film. How far can the film of oil spread over the water surface? Does it show that a drop of oil can spread in very thin layers? Scientists have devised methods to find the thickness of the thinnest layer and found it to be as small as 10^{-7} cm (the size of a molecule).

7.6. Atomic theory.

The atomic idea of the Greek philosophers was based more or less on guess and speculation. They did nothing to test their ideas, nor did they pursue the subject. For more than two thousand years, no

one took any serious notice of it. In the middle of the 17th century, Robert Boyle (1627-1691) of England conceived gases as consisting of myriads of particles. Sir Isaac Newton supported the idea of Boyle regarding the particle nature of gases. It was, however, John Dalton, a school master in England, who in 1808 propounded his famous '*Atomic Theory*' based on scientific experiments. His work marked the real start of the science of chemistry.

According to Dalton, matter consists of minute indivisible particles called *atoms*. The atoms of a particular substance are identical in all respects, namely, size, mass, weight and in other properties. The difference between substances is due to the difference in the atoms of these substances. He further thought that atoms, i.e. matter, could neither be created nor destroyed. This is known as the principle of *conservation of matter*.


Fig. 7 10

At about the same time when Dalton proposed his atomic theory some experimenters suspected that some substances broke up into 'new substances' when treated in a different manner, say, by heating or by pounding. Suppose you want to find out what sugar is made of. Heat a spoonful of sugar over a flame (figure 7.10). You notice a crackling noise. At the same time if you hold a cold knife blade over the sputtering sugar, moisture is formed on it. The crackling sound and the appearance of moisture on the knife indicates that water has come from the sugar. As the heating goes on, the sugar melts and darkens in colour, finally becoming as black as coal. Both coal and this black mass are carbon which cannot be broken down into anything simpler.

What about the water that came out of sugar? It turns out that this can be broken down further.

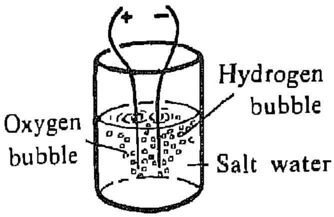


Fig. 7.11

At about the time of Dalton, it was shown that by connecting two wires to an electric battery and putting their ends to water, (figure 7.11) bubbles of oxygen gas came out at one end and hydrogen gas at the other end. These gases could not be broken up further.

7.7. Elements and compounds.

Substances such as carbon, hydrogen, oxygen, sulphur, iron, copper, silver, etc., totalling about one hundred that have been discovered so far are called chemical elements. An element, in turn consists of a collection of identical atoms of that element and nothing else. Hundreds of thousands of other materials and substances such as sugar, water, milk, oil, stone, salt, rubber, plastic, paper, etc., that you find in your surroundings are made of combinations of atoms of these elements. Such combinations of two or more elements are called *compounds*. Just as 26 letters in English alphabet make up millions of words, so these one hundred elements by combining among themselves have made this physical world of matter. Water which is liquid is a compound of two gases, hydrogen and oxygen. The common salt you use consists of a metal sodium and a gas chlorine combined in a definite way. You call this compound sodium chloride. You might never guess that the white salt crystals have got a light shining metal and a pungent greenish yellow gas mysteriously hidden in them.

In a chemical compound, the elements are present in a definite ratio. You will learn more about this in Chemistry. Of course there are substances which are *mixtures*. Air is such a substance consisting primarily of two gases, oxygen and

nitrogen. In a mixture, there is no chemical combination between the elements. Hence the properties of the elements are present in the mixture. But a compound has got properties entirely different from those of its elements, as you have seen in the case of water, common salt or any other compound.

Dalton decided to find out how much of each element is needed to form its compounds. He was astonished to find that whenever a compound of two or more elements was formed, the elements combined, i.e. joined together not in a haphazard manner but in a definite proportion by weight, say, 1 to 2, 1 to 3, 2 to 3 and so on. He, therefore, argued that the combination between elements means the combination between the atoms of these elements. And because an atom is the smallest unit and cannot be further sub-divided, the combination will take place in the ratio of whole numbers—1,2,3 and so on, of the atoms of the elements.

7.8. Molecule.

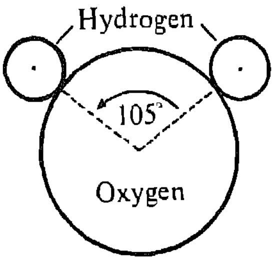


Fig. 7.12

It is actually found that for every part by weight of hydrogen, eight parts by weight of oxygen are required to form what is called one *molecule* of water. A molecule is thus the smallest particle of a compound just as an atom is the smallest particle of an element. An oxygen atom is 16 times heavier than an atom of hydrogen. A molecule of water consists of two atoms of hydrogen joined to one atom of oxygen in the ratio of 1:2, in a manner shown in figure 7.12. In any compound, the atoms of the elements are joined together in a fixed ratio. In sodium chloride (common salt), one atom of sodium is joined to one atom of chlorine to form a molecule of sodium chloride in the ratio of 1:1.

You thus find that the atomic theory explains the structure of matter more clearly. It tells us that all materials and substances in this physical world are made up of atoms and molecules. The 'building bricks' of the world of matter, not of one kind, but of about one hundred varieties, have thus been discovered. A few common substances (compounds) along with the elements that compose them are listed below.

Compounds	*Elements*
Water	Hydrogen, Oxygen.
Common salt	Sodium, Chlorine.
Sugar	Carbon, Hydrogen, Oxygen.
Sand	Silicon, Oxygen.
Marble	Calcium, Oxygen, Carbon.
Quick lime	Calcium, Oxygen.
Blue vitriol (copper sulphate crystal)	Copper, Sulphur. Oxygen, Hydrogen.
Carbon dioxide	Carbon, Oxygen.

The number of chemical compounds known today is more than a million and a half. In all of them, the atoms of the elements forming the molecules of these substances play their decisive role. This is the strongest evidence of the atomic theory of matter. You will learn more of it in Chemistry.

7.9, Are atoms real ? Sizes of atoms and molecules.

You may be curious to know whether atoms exist in reality or whether it is simply an idea, a kind of guess work just like that of the Greek philosophers. Can we see atoms ? How big are they ? Are there any direct evidences to show that atoms and molecules do exist ?

As a student of science you should know that 'seeing is not always believing'. Our eye-sight and other senses are not always reliable. On the contrary, scientists have devised and invented tools and instruments more accurate and sensitive than our sense-organs. With the help of these instruments, experiments have revealed the existence of atoms and molecules beyond doubt. The size of an atom is unbelievably as small as 10^{-8} cm. Can you form an idea how small it is ? If 1 cm is divided into ten crores of equal parts, then one such part will be the size of an atom. The present world population is about 30×10^{8}, i.e. about 300 crores. If all the population of the world is represented on a scale by 1 cm, then only 30 people out of the entire world population will be represented by an atom. Your thumb is about 5 cm long, 2 cm across and 1 cm thick. With atoms each of about 2×10^{-8} cm in diameter, this is $\frac{5}{2} \times 10^{8}$ atoms long, $\frac{2}{2} \times 10^{8}$ or 10^{8} atoms across and $\frac{1}{2} \times 10^{8}$ atoms thick. Your thumb, therefore, contains about 10^{24} atoms. Can you believe this ? But it is true and is an average estimate of the number of atoms in a small quantity of matter. A tiny drop of water at the tip of a needle contains about 10^{18} water molecules. If molecules could have been magnified to the volume of grains of sand, then a handful of sand would have contained enough molecules to cover the entire surface of the earth. Billions of atoms make up the ink in the dot put after a sentence.

7.10. Molecular and atomic mass

It is this smallness of an atom, this staggering number of atoms in a speak of dust or a drop of water or in an ink dot that makes atoms and molecules so difficult to be detected with unaided

senses. Electron microscope and field ion microscope with several million times magnification have, however, succeeded in locating the position of atoms and molecules.

You have read in your Chemistry class that one gramme-atom of any gas at normal temperature and pressure contains 6.0×10^{23} atoms. This number is known as Avogadro's number. Therefore, 1 g of hydrogen contains 6.0×10^{23} atoms. So, the mass of a hydrogen atom is

$$\frac{1}{6 \times 10^{23}} \text{ g} = 1.67 \times 10^{-24} \text{ g}$$

Hydrogen is the lightest element and hence its atom is the lightest of all other atoms of the 103 elements discovered so far. A hydrogen molecule contains two atoms and its mass is twice the atomic mass of hydrogen.

Exercises.

1. Suppose that the mass of a water molecule is 3×10^{-3} g. Calculate the number of molecules in 1 gramme of water of volume 1 cc. Also find the volume occupied by a water molecule.

2. If 1 gramme of sugar contains 1.75×10^{21} molecules of sugar, calculate the mass of a sugar molecule. Is it heavier than one water molecule ?

3. Take one gramme of potassium permanganate containing 1.75×10^{21} molecules and dissolve it in a litre of water. Take 1 cc of this solution and put it in another beaker containing one litre of water. Find —

(i) potassium permanganate in g per cc of the second solution.

(ii) number of potassium permanganate molecules per cc of the second solution.

4. When 1 cc of water becomes steam, it occupies about 1000 cc. If the molecules retain the same volume as in water, calculate the ratio of the volume of space available to each molecule of steam to the volume of the molecule itself.

7.11. Crystals.

Have you observed the regular geometric shapes of crystals of substances like common salt, sugar, copper sulphate, alum ? Whether the crystals are large or small, the particular shape of the crystals remains the same. The regular shapes indicate that such solids are built up of layer upon layer of many crystal-building blocks arranged in a regular pattern. If you examine a piece of mica, you will find that it looks like a number of pages of a book taken together. The layers can be easily separated. Calcite crystals even when broken into small parts retain its characteristic shape.

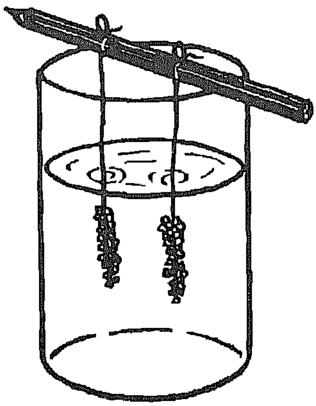
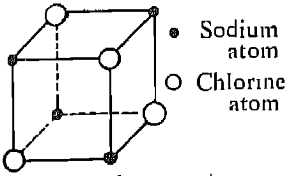


Fig. 7.13

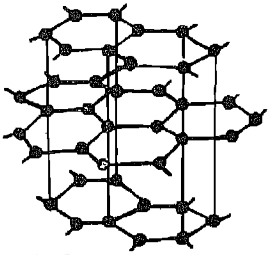
You can do the following experiments to study the growth of crystals of some substances.

Pour sugar in a cup of boiling water. Go on adding sugar and stirring the solution until a fine layer appears at the bottom. Allow the solution to cool. Filter it through a folded cloth. Do you see any sugar in the solution ? Taste it and be sure that sugar is present in the solution. Now hang a few threads in the solution from a pencil (figure 7.13). In a few hours, small sugar crystals with their characteristic shape will be formed round the threads. In the same way you can study the growth of crystals of copper sulphate and alum from their saturated solutions.

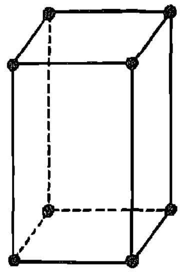
In each crystalline substance, the atoms are arranged in a regular pattern which gives the shape of



Sodium chloride crystal



A Graphite crystal
• Carbon atom



Sulphur crystal
• Sulphur atom

Fig. 7.14

the crystals, such as cubic in common salt, hexagonal in graphite (carbon), rhombic in sulphur etc. (figure 7.14).

Metals and many other substances are crystalline in structure. The attached picture (figure 7.15) (taken by a Muller field ion microscope with 2,700,000 times magnification) of the tip of a tungsten wire shows the arrangement of atoms in the crystal. The regular patterns or cells in the crystals form the bulk of the substance in a repetitive manner. With the help of X-rays, this structure has been studied in its minute details. Although atoms and molecules, because they are very small, cannot be seen even with the help of the most powerful microscope, yet the field ion microscope has shown the locations and motions of atoms or groups of atoms.

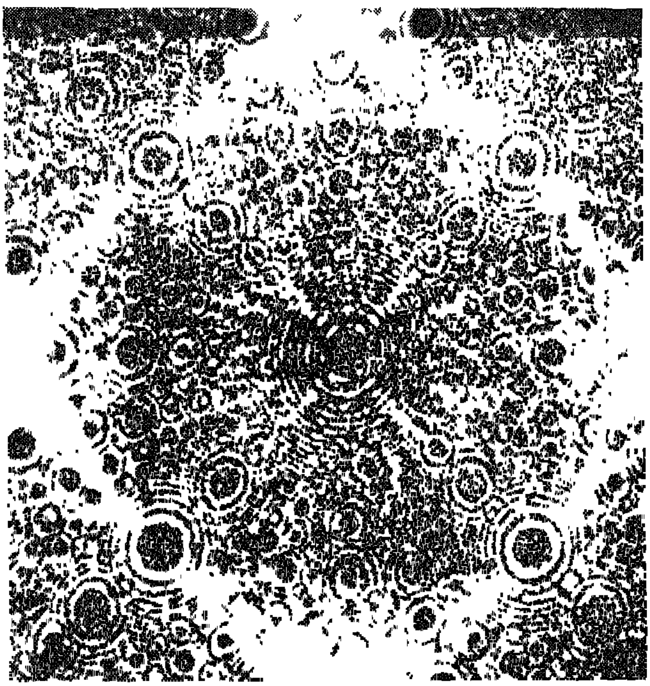


Fig. 7.15

7.12. Inter-molecular space—matter is porous.

(i) Test a balloon for leaks after filling it with water. Water does not leak out showing that there are no leaks in the balloon. Now half fill it with an indicator solution such as litmus and lower the balloon into a large jar containing ammonia water, (figure 7.16). Observe what happens. After some-time, the indicator solution changes to blue showing that some molecules of ammonia have passed through the walls of the balloon. The spaces through which ammonia has entered into the balloon are called pores and the material of the balloon is said to be *porous*.

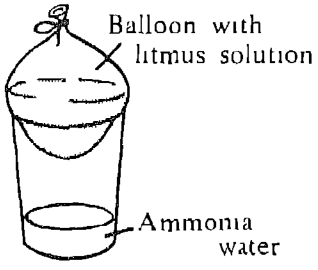


Fig. 7 16

(ii) An inflated air-tight balloon is found to shrink in size after some days. Where has the air in the balloon gone ? How has it gone ? Keep the air-tight balloon in a jar containing some perfume without touching it. After two to three days open the mouth of the balloon and smell the air as it escapes. Do you get the odour of the perfume ? How can it happen ? Does it suggest that the walls of the balloon are porous ?

(iii) Prepare a saturated solution of copper sulphate by dissolving powdered crystals in warm water. Pour water carefully along the side of the beaker without disturbing the solution of copper sulphate (figure 7.17). Copper sulphate solution of blue colour will be found distinct from water. After some days, the whole mass of the liquid will be found to have the same colour, light blue. This suggests that some molecules of copper sulphate after dissolving have filled the spaces between water molecules and vice-versa.

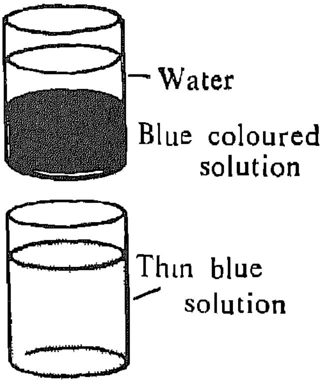


Fig. 7 17

(iv) Place about 30 cc of finely powdered sugar in a measuring jar. Add 200 cc of water to it. The total valume is 230 cc. Now stir the solution

thoroughly so that the sugar dissolves completely (figure 7.18). Note the total volume of the solution. Is it 230 cc or less ? It will be found to be nearly 207 cc, showing a decrease in volume by about 10 per cent. Sugar molecules have gone to fill up the spaces between water molecules.

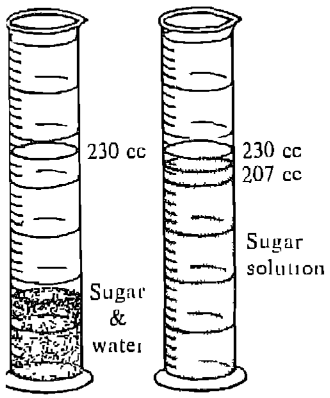


Fig 7 18

Question

Equal volumes of water and alcohol when mixed together result in a volume much less than the sum of the two volumes How can you account for this decrease in volume ?

From the above experiments, it follows that atoms and molecules leave space between themselves when they combine to form a substance.

7.13. Molecular forces.

If matter consists of small particles like atoms and molecules, what holds these particles together ? The atoms and molecules are obviously held together by strong forces. The following experiments and examples will show the presence of these forces.

1. Pull a rubber band and stretch it with an increasing force. Release it. What makes it regain its original length ? Does it show that the molecular attraction in the rubber has restored it to its original length and shape ?

Repeat the experiment with a steel or copper wire. Is a greater force necessary to extend it by the same amount ? Does it prove that the molecular forces are greater in these substances than those in rubber ? This force between the molecules is called *cohesion*. It is this cohesive force that holds the molecules together. It is different in different substances. It is very strong in steel such that a steel cable of 2 cm diameter can support a heavy railway engine.

2. Take two strips of glass plate and place one over the other with a few drops of water in between them. Try to separate the two strips. Is it necessary to apply force to pull them apart ? Does it prove that there are forces between water and glass ? Water sticks to the glass because of molecular force between water and glass. This type of molecular force between the molecules of different substances is called *adhesive force*. Why are glue and paste sticky ? You use adhesive tapes for binding. The binding is done by the force of adhesion between two different substances. Oil molecules are strongly attracted to steel. Lubrication of machine bearings depends on this adhesive force which keeps in position an oil layer between the surfaces of the bearings.

Exercises.

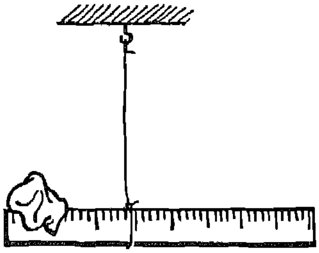


Fig. 7 19

1. Suspend a metre scale from a support in your room with your wet handkerchief placed at one end (figure 7.19). Let it hang horizontally. Can you suspend it at its middle part ? If not, why not ? What do you expect to see as the handkerchief dries ? Is the wet handkerchief losing weight ? How ?
2. Does air contain water vapour ? How can you show that the air in your room contains water vapour ?
3. You are given crystals of common salt, sugar and blue vitriol. How can you make them invisible, although you may be sure of their presence ? How can you make them reappear and visible ? Examine a few particles of these substances and name their particular shapes, if any.
4. Examine a toy balloon. Do you find any pores it its wall ? Suggest some experiments to show that your toy balloon is porous. Take two balloons of nearly same size, one of rubber and the other of plastic. How can you test which is more porous ?

5. How can you show that liquids like water, alcohol (spirit) and copper sulphate solutions have inter-molecular space ?

6. What is the force that holds the molecules together ? What are adhesion and cohesion ? How can you account for the following :

(i) Sticking of water on glass.

(ii) Binding capacity of glue and adhesive tape.

(iii) Use of lubricating oil in machine bearing.

(iv) A steel wire can support a heavier load than a rubber band of the same thickness.

(v) It is difficult to pour out coal tar or honey.

7. Put two dozen marbles in a wide mouthed bottle. Shake the bottle. Do you see spaces between the marbles in the bottle ? Now put a few handfuls of sand in the bottle. Shake it. Do you see the sand looking from the top ? Do you find any analogy between this experiment and those in exercise 3 and 4 above ?

7.14 Range of molecular action—solid, liquid and gas.

The molecular forces are very great when the distances between the molecules are small. If the distance increases and exceeds a certain limit, the forces become weak. They can no longer hold the particles together. When you tear a leaf or a paper or break a piece of glass or any other substance, the force applied overcomes the resistance (molecular forces) offered by the substance. The broken parts of the substance cannot be held together as they are beyond the range of molecular attraction, also called the *sphere* of each other's influence.

Molecular forces of attraction are the strongest in solids and the molecules are closest, almost 'touching' each other. This is why solid has got a

definite shape and size and offers resistance to the forces trying to deform it. The molecules in a solid can, however, vibrate backward and forward about their mean position in much the same way as a pendulum in a clock. In liquids, the forces are not as strong as in solids. So, the molecules in a liquid can move 'freely' among themselves. They cannot, however, go away leaving their 'friends'. This is why liquid has got no shape of its own. But as the molecules cannot go away beyond a certain range, a liquid has got a definite volume. In gases, the molecular forces are very very weak, almost negligible. The molecules can, therefore, move at random in all directions. This explains why a gas has neither a shape nor a volume and occupies any space made available to it. Hence a gas requires an enclosed space to kept it confined.

Fig 7.20

7.15. A Model

Take a wooden tray. Fill half of it with marbles of identical size. Tilt the tray slightly and shake it gently and continuously (figure 7.20). You will see marbles almost touching one another and also vibrating to and fro. This is a model, a crude one, of close and regular packing of molecules, as in solids.

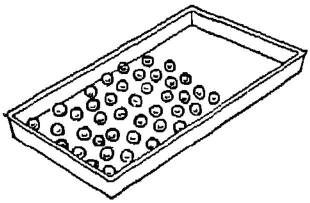


Fig 7.21

Now remove about one fourth of the marbles and shake the tray again. Now the marbles can move from place to place. There is no regular pattern of arrangement (figure 7.21). This is a model of molecular arrangement in liquids.

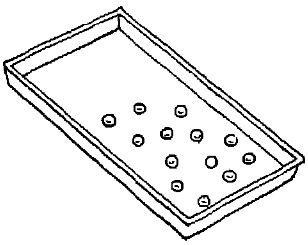


Fig 7.22

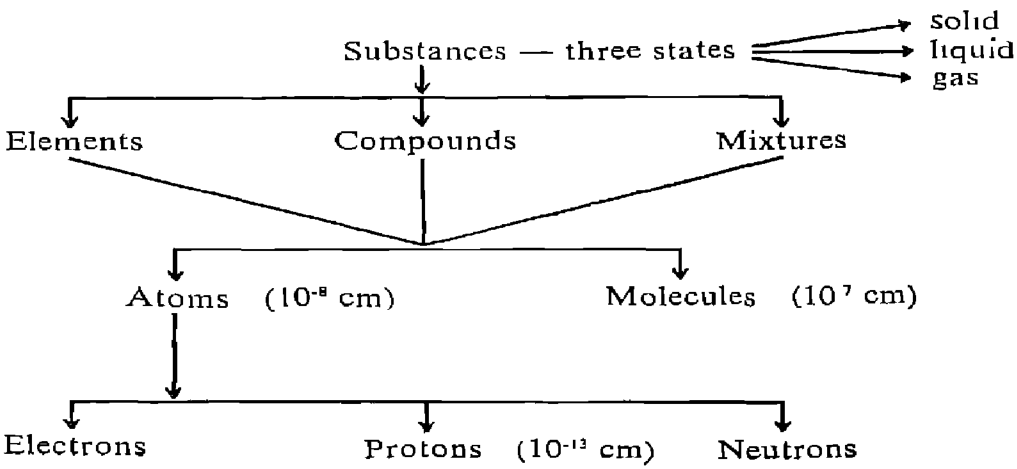
Now, remove about three fourths of the marbles from the tray. Shake the tray vigorously (figure 7.22). What do you find ? Do the marbles move at random ? In gases, the molecules are arranged in a similar way. Of course, these are only models and a molecule is about one billionth in size of a small marble and

moving at a tremendous velocity. A molecule in air bumps into other molecules about five billion times a second.

7.16. Particles Smaller than Atoms

Dalton's atoms once considered to be the smallest indivisible particles have been found to be no longer so. There are much smaller particles in an atom—electrons, protons and neutrons about which you will learn when you study electricity. Those are the 'building blocks' of matter.

Summary



Exercises

1. Fill in the following gaps with correct word (s) .

(i) An atom is the .... indivisible .... of an ....

(ii) A molecule is the ... . particle of a . ....

(iii) A compound is a .. ... of two or more . ...

(iv) Water is a ...., but air is a ....

(v) Water is composed of two .... , namely .... and ....

(vi) Molecular forces are strongest in .... and .... in gases.

(vii) .... is the founder of the atomic theory.

(viii) According to the Greeks, the word atom means ....

(ix) The idea of a molecule was given by ....

2. Name five phenomena or give five examples showing—

(i) granular structure of matter

(ii) inter-molecular spaces

(iii) molecular forces.

3. When elements combine to form a compound, can they do so in any manner? Illustrate by giving an example.

CHARGES AT REST

8.1 Introduction

If you are in the habit of collecting feathers you may be having a peacock feather with you. Start your lesson with one of them. On rubbing a peacock feather in between the pages of the book, you can make it spread like a fan or make it bend towards the kunckles of your finger (figure 8.1) or make it lift small bits of paper. Why do the feathers behave like this after rubbing ? Do other bodies behave in a similar fashion ?

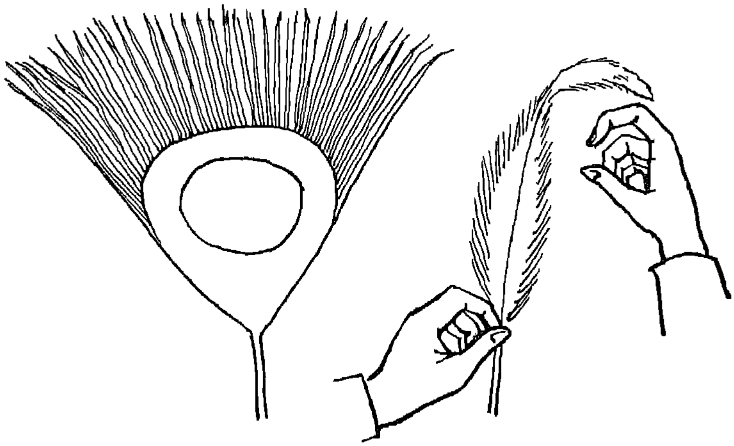


Fig. 8 1

Do some experiments and see for yourself whether other bodies also behave in the same way.

Tear a piece of paper to bits and scatter them on a table. Take a comb and bring it near the bits of paper. The bits of paper are not affected by the presence of the comb. Now brush the comb through dry hair. Do you find it difficult now to comb the hair ? Do you hear any crackling sound ? Bring this comb near the bits of paper. What do you observe ? The bits of paper are attracted towards the comb. Is it not suprising that the

comb also acquires the property of attracting paper bits only after brushing (rubbing) through dry hair ?

Activity

Rub different bodies such as a wooden scale, a plastic scale, a rubber balloon, a pencil, a fountain pen, a glass rod, an eraser, a copper rod, a ten-paise coin, a polythene bag, etc. with different pieces of fabric such as cotton, silk, wool and terylene. See whether these bodies also attract bits of paper after they have been rubbed. Record your observations. What do you infer from these observations ?

In most cases the bodies acquire the property of attracting small bits of paper. In a few cases like those of a coin, or a copper rod, you find that the rubbed body does not seem to attract paper bits. You will certainly like to know the cause of this difference in their behaviour. Hold the copper rod by a wooden handle and now rub it with woollen cloth and find what happens. You know that wood is a bad conductor of electricity whereas copper is a good conductor. Can you draw any inference from these observations ?

Activity

Take a battery, connect it to a torch bulb holder. Join them through the clips A and B as shown in figure 8.2. Touch the two free ends to test that the bulb glows and the circuit is alright. Hold each of these bodies such as a glass rod, a plastic scale, a copper rod, etc. in between the clips and find out in which case the bulb glows and in which case it does not glow. Do you find any cause for the differences in their behaviour ? Take a

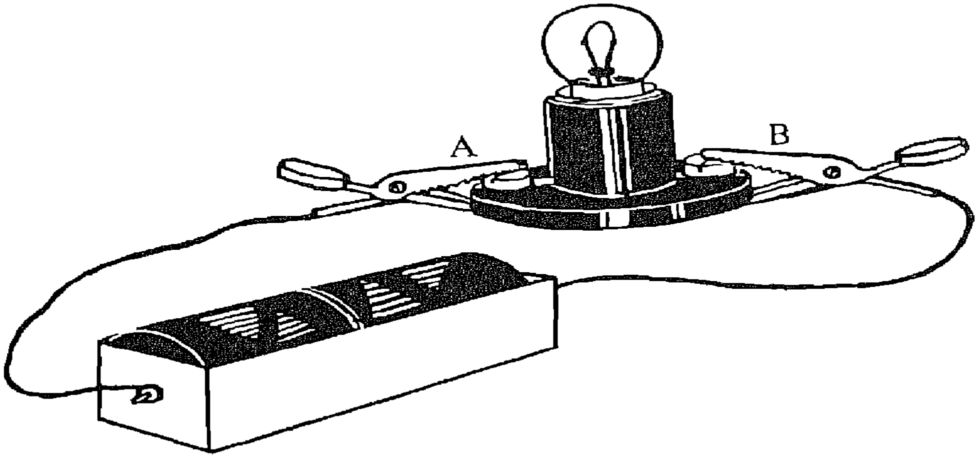
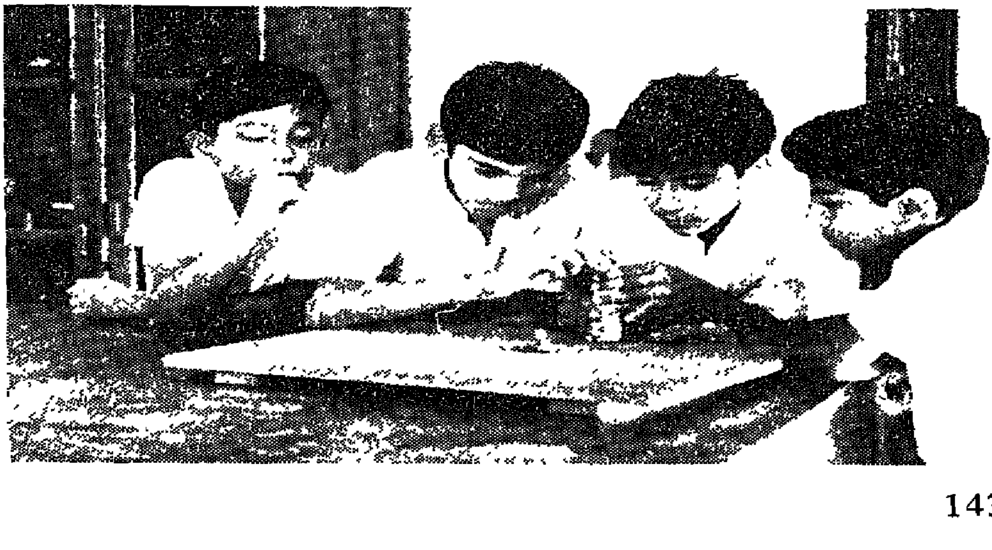


Fig. 8.2

glass tube with one end drawn out into a narrow jet. Connect the broader end of the tube to a tap. Open the tap slowly. A fine stream of water will come out of the jet. Bring a glass rod near the jet. What do you observe ? Now rub the glass rod and bring it near the jet. What do you observe now ? You will see that the rubbed glass rod attracts a jet of water.



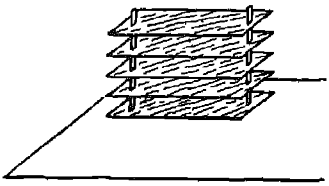


Fig 8.3

Take a plastic scale and rub it against a piece of terylene. Bring it near dust particles in a corner of a room. You will see that the dust particles are attracted towards the scale. Take a number of plastic sheets and rub them by the same piece of terylene. Arrange them as shown in figure 8.3. Keep them in a corner of the room. After some time you will see that dust has accumulated on these sheets, A machine called electrostatic dust collector (figure 8.4) has been made on this principle.

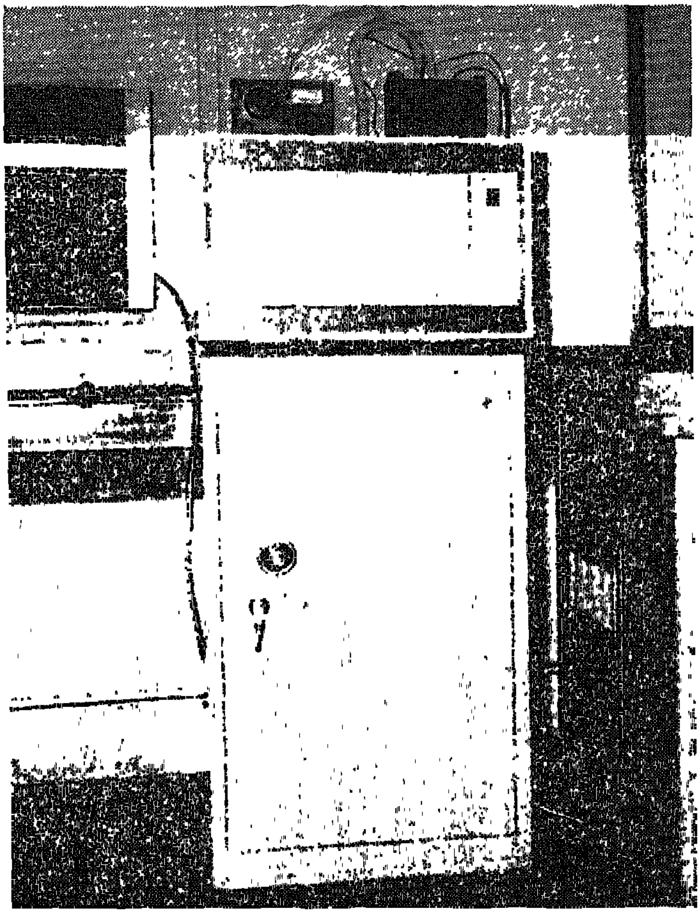


Fig. 8.4

Take a glass tumbler and put a thali on top of it. Take a polythene bag and rub it against the wall. Put it on the thali promptly after rubbing. After some time remove it, rub it against the wall and place it on the thali once again. Repeat it several times. Then bring the knuckle of your finger near the thali. You will hear a crackling sound and in a dark room you will see a spark between your knuckle and the thali.

On a dry day when you take off your terylene shirt, what do you observe ?

Have you noticed that dirt and dust particles stick more easily on woolen and silk clothing as compared to cotton ?

In all the experiments, you have seen that bodies acquire the property of attracting lighter bodies only on being rubbed against some other body. The fact that bodies on being rubbed acquire this peculiar property was known for a long time. It was discovered around 600 B. C. by Thales, a Greek philosopher. He showed that an amber when rubbed with wool acquires such a property. He called this property *electricity* from the word *elektron,* which is a Greek word for amber. It may be stated that bodies get *electrically charged* after rubbing. This charge is therefore produced during the process of rubbing and the rubbed bodies get charged.

Activity

Rub the following substances against each other. Bring each of them near bits of paper and note down what you observe :—

Ebonite rod against wool.

Plastic scale against a piece of cloth.

Rubber balloon against a piece of cloth.

Polythene bag against a wooden rod.

From these experiments you can see that both the bodies involved in the process of rubbing get charged. Now try to find out whether the charges on all the bodies are of the same nature.

Take a glass rod, rub it at one end with a piece of silk cloth. Place the rod on an inverted watch glass such that it is balanced (figure 8.5).

Fig. 8.5

Take another glass rod, rub it with silk and bring it near the rubbed end of the first rod. What do you observe? Rub an ebonite rod with woollen cloth and bring it near the rubbed end of the glass rod on the watch glass. What do you observe? You see

that in one case there is repulsion between the two charged bodies whereas in the other case there is attraction. Thus you see that the two charged bodies exert either a push or a pull on each other.

You have seen from the above experiment that two glass rods rubbed against silk cloth repel each other.

Activity

Rub a glass rod with a silk cloth and suspend it with a piece of thread as shown in figure 8.6. Take an ebonite rod, a glass rod, a plastic scale, a polythene bag, a rubber balloon, etc. and rub them with a piece of cloth, wool, silk cloth and terylene. After rubbing bring each of the bodies near the suspended charged glass rod and observe whether these bodies exert a push or a pull on the suspended body. Classify from amongst these bodies those which exert a push on the suspended glass rod and those which exert a pull on it. What inference can you draw from these observations ?

Fig 8.6

You will see from this experiment that when a glass rod rubbed with silk is brought near the suspended glass rod, it exerts a push on it, whereas the silk cloth exerts a pull on the suspended glass rod

You might therefore say that during the process of rubbing two different types of charges are produced on the two bodies which are rubbed one against the other. Verify this in each of the above pairs of bodies.

It is natural to suppose that when two glass rods are rubbed with silk they should get the same type of charge. By convention this type of charge is called positive charge, whereas the charge acquired by silk on being rubbed with glass is called negative charge.

Activity

From the pairs mentioned in the previous activity, find out those bodies which acquire a positive charge and those which aquire a negative charge. Verify doing series of experiments that two similarly charged bodies will exert a force of repulsion, whereas two dissimilarly charged bodies will exert a force of attraction on each other.

Take a glass rod, rub it with silk and suspend it with a silk thread. Take another glass rod, rub it with a piece of silk and bring it near the suspended glass rod. You will observe a force of repulsion between them. Next bring the silk cloth against which the glass rod was rubbed near the suspended glass rod. You will find that there is a force of attraction. Now take an uncharged glass rod and rub it with silk. Without removing the glass rod from the silk

cloth bring the combination, i.e. the glass rod and the silk cloth near the suspended glass rod. What do you observe ?

You can see by series of experiments that when two bodies are rubbed together, the two acquire opposite charges, but two taken together do not exhibit any charge. This leads to the idea that when two bodies are rubbed together, they acquire opposite but equal charges.

Activity

Charge a glass rod and suspend it with a thread. Rub another glass rod with silk and bring the silk cloth near the glass rod. You will find that there is an attraction between the suspended glass rod and the silk cloth. Now suspend an ebonite rod rubbed with wool and bring the rubbed silk cloth near the ebonite rod. You will find that there is a repulsion between the charged silk cloth and the suspended charged ebonite rod. Bring an uncharged plastic scale near the suspended charged glass rod and suspended charged ebonite rods in turn. What do you observe ? You will find that in both these cases there is an attraction between uncharged plastic scale and negatively charged glass rod and also between the positively charged ebonite rod and the uncharged plastic scale.

It is seen from the above experiment that two unlike charged bodies attract each other. It is also seen that there is an attraction between a positively or negatively charged body and an uncharged body.

Thus when there is an attraction between a charged body and another body it will be difficult to say whether the latter is oppositely charged or uncharged. Can you find out any method by which you can tell whether the body is charged or not ? It is only when two bodies are charged with the same type of charge that there is a force of repulsion between them. Thus if two bodies repel each other, one can safely conclude that both of them have the same type of charge. This is sometimes expressed as "*Repulsion is a surer test of electrification*".

8.2 An electroscope

A lot of simple instruments can be designed to detect the presence of charge on a given body. The suspended charged glass rod can itself be a device of detecting a charge on any other body. You can make it still simpler by suspending a plastic sphere (ping pong ball) with a piece of thread. In order to make it more convenient, the plastic sphere can be covered with a thin aluminium foil or the wrapper from a cigarette packet. Make one such for yourself and use it to detect the type of charge on various bodies after rubbing them against a piece of cloth, silk cloth, woollen cloth, etc.

You can yourself make another charge detecting instrument, called *electroscope*, with a straw.

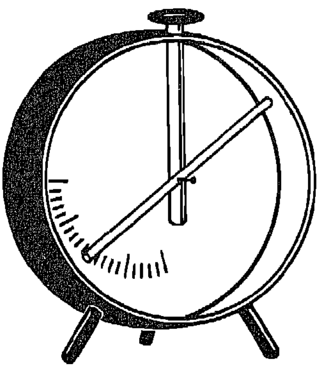


Fig. 8 7

Take a plastic box as shown in figure 8.7. Take a straw and cover it with cigarette wrapper. Fix a pin in the centre of the straw and put it on the metal stand fixed in the plastic box as shown in figure 8.7. On the back side of the box fix a paper on which graduations are made as shown in the figure. Make such an electroscope and use it to determine the type of charge on various bodies when rubbed against other bodies.

Question

Does the amount of charge depend on the extent of rubbing? Rub the same pair several times and see what happens?

8.3 Gold Leaf Electroscope

A more sensitive instrument can be constructed by using commonly available things.

Take a rectangular wooden box provided with glass panes on two sides. Clean and dry it thoroughly. Take a small aluminium rod bent at right angles at one end and pass it through the upper lid of the box. At the upper end place an aluminium pan as shown in figure 8.8.

Fig 8 8

ig. 8 9

You have been supplied with aluminium coated thin plastic foils in your kit. Fold a foil and gently put it on the right angle bend of the aluminium rod as shown in the figure. Your electroscope is ready for use. Rub a glass rod with a silk cloth a number of times and touch it to the aluminium pan You will find that the foil at the other end spreads out as shown in figure 8.9.

Why does the foil spread apart ? (*Hint :* Aluminium is a good conductor of electricity.) With this electroscope you can as well determine the type of charge acquired by various bodies on rubbing.

Activity

Take an electroscope. Touch the pan of the electroscope with a glass rod rubbed with silk. The leaves get the same type of charge as that on the glass rod. Bring another glass rod rubbed with silk and touch it to the pan. What do you find ? Now touch the silk cloth to the pan. What happens to the leaves ? Is there any change in the divergence of the leaves ? Can you explain why this happens ?

8.4 Mechanism of Electrification During Friction

You have seen that during the process of rubbing, or during the process of friction, bodies get charged. You will now find out why bodies get charged during friction. Is there anything that happens besides developing the charge during friction ? Rub your hands together. What happens after rubbing ? Take a stone and rub it very hard against another stone. You will find that the stones get hot. In some cases you can even see light coming out during the process of rubbing. Thus you see that during friction not only charge is developed but also heat is produced in the bodies which are rubbed together.

In the previous chapter you have read that matter is made up of atoms and molecules. These atoms are electrically neutral. An atom consists of a positively charged heavy nucleus, surrounded by revolving electrons which are negatively charged. An

atom of one substance differs from the atom of another substance in the constitution of the nucleus as well as in the number of electrons that move round the nucleus. However, atoms of all substances are electrically neutral, implying that the positive charge on the nucleus of an atom is equal to the charge on the electrons which revolve round the nucleus. During the last fifty years physicists have made a detailed study of the atomic nucleus which has yielded considerable information regarding the constitution of the nucleus. The study of nucleus is extremely interesting and forms a field of study which is called *nuclear physics*. You will learn more about this as you advance in your study of physics. The nucleus consists of two types of particles : (1) protons and (2) neutrons. Both these particles have more or less the same mass which is roughly 2000 times the mass of an electron. The neutron is an uncharged particle whereas the proton has a positive charge equal in magnitude but opposite in sign to that of the charge of an electron. In every atom there are as many protons as there are electrons. As mentioned earlier, the atoms of different elements differ from each other in respect of the number of electrons, the number of neutrons and the number of protons. Thus, for example, a hydrogen atom has one proton in the nucleus and one electron moving round the nucleus in almost a circular orbit with a radius of roughly 0.5Å. The helium atom has two neutrons and two protons in the nucleus and two electrons moving round the nucleus in almost a circular orbit with a radius of 0·25Å. The figure 8.10 shows schematically the structure of the atoms of a few commonly known elements. You will find in this figure that all the electrons in a given atom do not revolve round a nucleus

in the same circular orbit. You will learn in future how the electrons in an atom are distributed among different orbits known as *shells.* The reason why

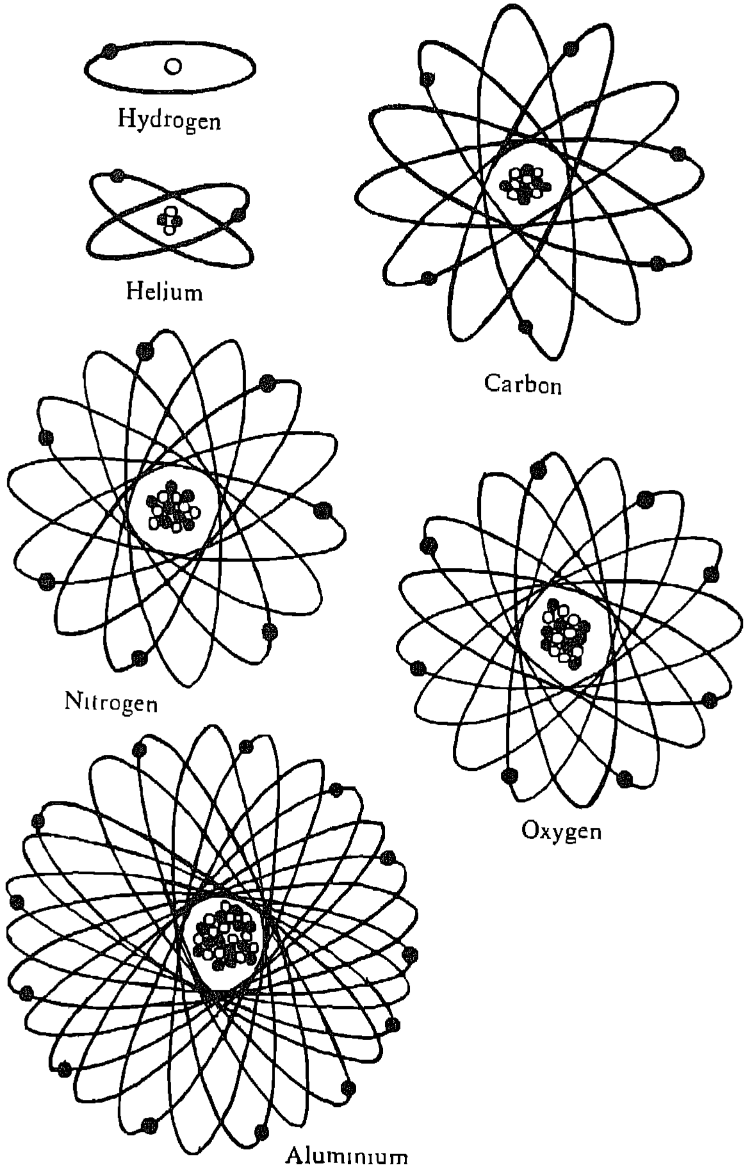


Fig. 8.10

only a definite number of electrons and not more can be acccommodated in a given orbit will be clear as you know more about atomic structure.

At this stage it is enough to know that atoms of all elements though electrically neutral consist of positively charged nucleus and negatively charged electrons revolving round it. These electrons are held to the nucleus by the force of attraction between the positively charged nucleus and the negatively charged electrons. The atom is something similar to the solar system. The sun is at the centre and the number of planets are moving round it in different orbits. In the atoms, a positively charged nucleus is at the centre and the electrons are moving round it in various orbits.

It may be mentioned that all electrons are identical in respect of their charge and the mass. Similarly all protons are identical in respect of their charge and the mass. Since electrons are held to the nucleus by a force of attraction between a nucleus and the electrons, it is clear that if one can pull the electrons out with a force greater than the force of attraction, then the electrons can be freed. One can provide this sort of a pull by either heating or compressing the atoms under very high pressure. When you heat a substance very strongly, its atoms begin to move very fast and shake off some of their surrounding electrons which become 'free'.

It may now be easy to understand how charges are produced during friction. You have seen that when two bodies are rubbed together, essentially because of friction between them, heat is produced. The figure 8.11 shows a magnified picture (as seen through a microscope) of the surface of a machined iron rod which to a naked eye, appears very smooth.

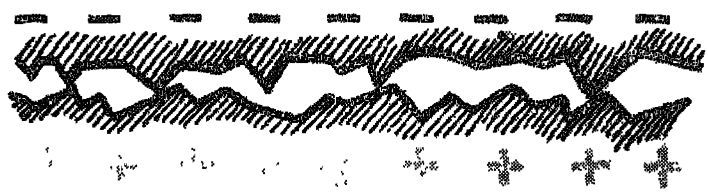


Fig 8.11

Most of the surfaces have an appearance like the one shown in the figure. When two such surfaces are rubbed one against another, the hills on one collide against the hills on the other and produce heat. Professor Bowden of the Cambridge University made a systematic study of the phenomenon of friction between two surfaces. He showed that when the two surfaces are rubbed one against another, there are certain small regions on the surface which are raised to very high temperature (as high as 2000°C). These regions are however extremely small in size and hence you can not feel or measure the rise of temperature by ordinary means. When such temperatures are produced during friction, electrons held to atoms at these places become free. They then have a choice either to get back to the surface from which they came or go to the other body. When electrons from one surface go over to the other, the body which has lost the electrons, has more positive charge on it whereas the body which has taken up these electrons has more negative charge on it. From this process of electrification by friction, it is clear that two bodies when rubbed together acquire equal but opposite charges.

Since the mechanism of electrification by friction implies the transfer of electron from one body to another, the charge acquired by the body which has taken electron will obviously be equal to the number of electrons taken multiplied by the charge of an electrons. Similarly, the positive charge acquired by the body which has lost electrons will again be equal to the number of electrons lost multiplied by the charge of an electron. The number of electrons taken in or lost by a body must necessarily be an integral number such as 1, 2. ......5 . .100 . ....500 as electrons cannot be split. *It is thus clear that any charge produced by friction must be an integral multiple of an electronic charge.*

9 FORCE BETWEEN CHARGES

9.1 Introduction

In the previous chapter you have seen that several bodies e.g., a glass rod, a plastic scale, a polythene bag, etc., when rubbed with silk-cloth acquire the property of attracting small bits of paper, saw dust, cereal grains, etc. You know that in the process of rubbing, the two bodies which are involved, acquire equal and opposite charges. Now try to inquire about the force that exists between the two charged bodies.

Activity

Suspend a long glass rod horizontally with the help of a silk thread. Rub its one end with a silk cloth. Bring another rubbed glass rod near it. What do you observe ?

Repeat the experiment with other rubbed bodies such as an ebonite rod, plastic scale, comb, etc.

Note down your observations by R for repulsion and A for attraction.

The above experiments show that between two charged bodies there is either a pull or a push. In other words two charged bodies exert either a force of attraction or a force of repulsion on each other.

Activity

(1) Charge a glass rod by rubbing it with a silk-cloth. Suspend the glass rod with the help of a silk thread. Bring another similarly charged glass rod near it. What do you observe ?

(2) Now bring the silk-cloth near one end of the suspended glass rod. What do you observe ? Is there a pull or a push between them ? Are the charges on the glass rod and the silk-cloth like or unlike ?

(3) Suspend a plastic scale. Rub one end with a piece of terylene cloth. Bring another plastic scale, also rubbed with terylene, near the suspended plastic scale. What do you observe ? Is there a pull or a push between these two similarly charged plastic scales ?

(4) In an earlier activity you have classified those bodies which acquire a positive charge and those which acquire a negative charge on being rubbed with a piece of cloth, such as silk cloth, woollen cloth and terylene cloth. Bring two positively charged bodies near to each other. Is the force between them, a push or a pull ? Again bring two negatively charged bodies near to each other. What do you find ? Do they attract or repel each other ? Now take two bodies one of which is positively charged and the other is negatively charged and find out whether they attract or repel each other.

In the above experiments you have seen that two charged bodies when brought near to each other attract or repel. In other words there is a force between the two charges. What type of force is that which acts between the two charged bodies ? Is it of the same type as that acting when you push a table or pull a chair ? In either of these two cases, there is a direct contact between your hand and the table. Two charged bodies push or pull each other even when they are not in contact.

Fig. 9.1(a)

Fig 9 1(b)

Activity

Take two small pith balls. Suspend them at some distance from each other with the help of pieces of thread from separate stands as shown in figure 9.1(a). Rub an ebonite rod with a piece of silk cloth and make it touch the balls one by one. Do you find any change in the positions of the two balls [figure 9.1(b)] ? Touch both the balls with your hand. Repeat the experiment by charging one ball with the ebonite rod and the other with the cloth.

In the first part of the above activity the two pith balls repel each other without being in contact. They attract each other in the second part of the activity, that is when they are charged oppositely still not being in contact with each other. For this force of attraction or repulsion a direct contact between the two charged bodies is not always necessary. This force between the two charged bodies acts at a distance. It can be experimentally found that this force of attraction or repulsion between the two charged bodies can act even in the absence of air.

Question

Do you know of any other force which acts at a distance ?

9.2 Direction of force

Activity

(1) Take a circular ring of radius 5 cm and fix it on a stand as shown in figure 9.2. Take a plastic sphere and fix it to a glass rod. Place this rod at the centre of the ring as shown in the figure. Suspend another

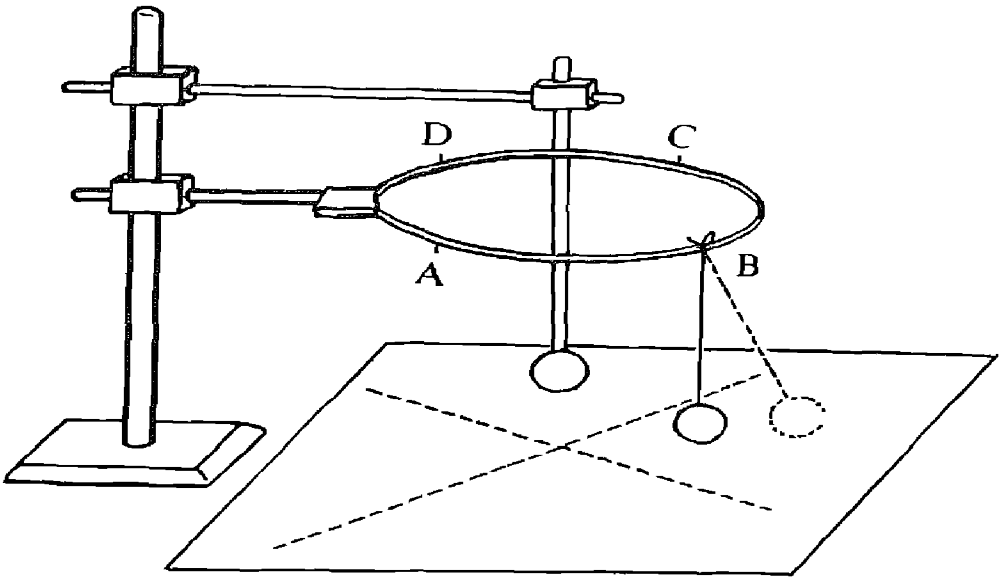


Fig. 9.2

plastic sphere from the ring with the help of a piece of thread. Charge both the spheres by touching them with a plastic scale rubbed with cloth. On a sheet of paper, placed on the table below the ring, note down the direction in which the suspended ball is pushed. Change the position of the suspended sphere by sliding the thread along the ring. Note down the direction along which the sphere is now pushed. Repeat the experiment by suspending the sphere from various parts A, B, C, D of the ring. In each case note down the direction in which it is pushed. Is it always along the line joining the centres of the two spheres ?

(2) Devise another experiment which will demonstrate the fact that the force between two charged spherical bodies acts in a direction joining the centres of the two spheres.

(3) Interchange the positions of the two spherical balls and repeat the experiment. What do you obseive ? Does the force act on both the charged bodies under consideration ?

From the above experiments you see that the force between two charged bodies are mutual i e , force acts on both the charges. Secondly, you have seen that the force between two charges whether it is a push or a pull acts along a straight line joining the centres of the two charged spheres. This shows that the force between charged bodies acts in a definite direction.

Question

Is the force between two charged bodies a vector or a scalar quantity ?

9.3 Magnitude of the force

You have seen that when two charged bodies are placed near each other, they exert a force of attraction or repulsion on each other depending upon whether the charges are unlike or like. Now can you say whether the force is always of the same value or it is different under different circumstances ? If so, on what factors does the force depend ? Try to find out answers to these questions from the following experiment :—

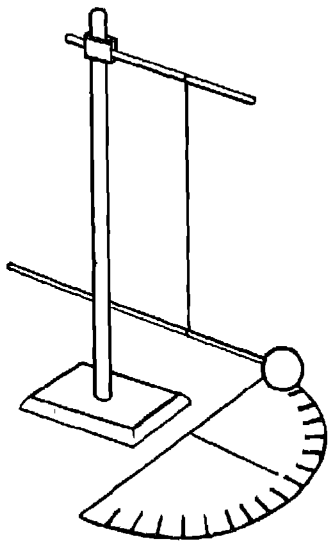


Fig 9.3

Take a plastic ball covered with a metal foil. Attach it with glue or thread to one end of a long glass rod. Suspend the rod by a thread such that the rod remains horizontal and steady in some position (figure 9.3) Give a small push to the plastic ball, The ball moves through some distance and the rod rotates about the thread. You can

measure the angle through which the rod rotates by placing a protractor below the rod on the table. The ball has a tendency to come back to its starting position. To keep the ball in the new position, the push has to be maintained. Give a larger push and you find that the rod moves through a larger angle. Thus you see that a larger push or force is needed to keep the ball at a larger angular distance from its original position.

9.4 Force depends upon charges

Activity

Take a glass rod with a plastic ball attached at one of its ends and suspend it with a thread. Place a scale below the ball such that the movement of the ball can be measured on the scale (figure 9.4). Take a metal ball and fix it on a wooden stand. Touch the plastic ball as well as the metal ball with a glass rod rubbed with silk. Place the metal ball at a certain distance from the plastic ball. Observe how much the plastic ball moves.

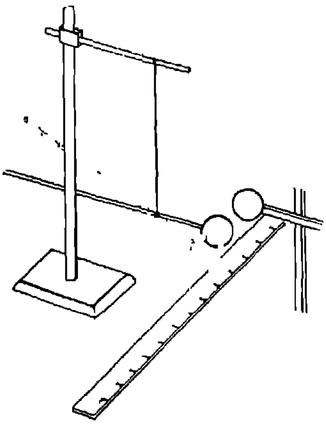


Fig 9.4

Give some more charge to the metal ball by touching it again with a rubbed glass rod. Note what happens.

Increase the charge on the metal ball still further. What do you observe ?

You see that the plastic ball is repelled by the metal ball as both have the same type of charge. The distance through which the plastic ball is pushed becomes larger and larger as the charge on the metal ball is increased. This shows that a larger charge on the metal ball exerts a larger force on the plastic ball. Thus the force between the two charged balls depends

upon the quantity of the charge on the metal ball. Greater the charge, greater is the force.

Activity

Repeat the above experiment by keeping the charge on the metal ball fixed. Increase the charge on the plastic ball.

Does the distance between the balls increase?

You see now that as the charge on the plastic ball is increased, the plastic ball moves through a larger distance from its original position. This shows that the force between the two charged balls also depends on the quantity of charge on the plastic ball.

The force between two charged bodies depends upon the magnitudes of charges on both the bodies. If any of the values changes, the force also changes.

Activity

(1) Repeat the previous experiment using a larger metal ball.

(2) Repeat the experiment when the two charges have opposite signs.

9.5 Force Depends on Distance

Activity

Take a few paper bits. Place these on the table. Rub a plastic scale or a comb with a piece of silk or woollen cloth. Bring the scale slowly nearer and nearer to the paper bits.

In the beginning the paper bits do not take any notice of the nearby scale. As the scale comes nearer, the pieces shuffle a bit or show a little restlessness. When the scale is brought still nearer the pieces stand

on their edges and finally when the scale comes very close they move towards the scale. How do you explain this behaviour of the paper bits ?

Activity

Suspend by a piece of thread a glass rod with a plastic ball fixed at one of its ends. Place a metal ball on a wooden stand near the plastic ball. Charge the two by touching each of them with a rubbed plastic scale. Move the metal closer to the plastic ball. What do you observe ?

You will see that as the metal ball is taken nearer to the plastic ball, the plastic ball moves further and further away. This shows that the repulsive force on the plastic ball increases as the metal ball comes nearer, i.e., as the distance between them decreases.

The above experiments show that the force between two charged bodies depends on the distance between them and the force increases as the distance decreases and vice versa. Such a dependence is called an inverse dependence. It was shown by the French physicist, Charles Coulomb in 1785, that the force between two charged bodies varies inversely as the square of the distance between them. When you reduce the distance to half of the initial distance, the force becomes four times larger. If you make the distance one-third, the force becomes nine times larger, and so on.

Coulomb arrived at the inverse square dependence of the force between two charged bodies with the distance, with the help of an instrument called the torsion balance. You can do the same experiment by using the principle of the ordinary balance.

The apparatus for the experiment is as shown in figure 9.5.

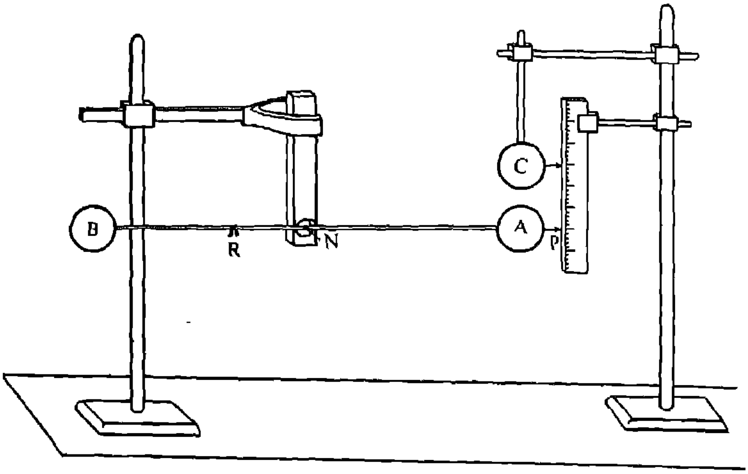


Fig 9.5

A and B are two hollow spheres made of copper. They are fixed at the ends of a thin metal rod one metre long. The rod is supported on a nail N fixed to a metal stand. C is a metal sphere identical with A and is placed above A at a distance which can be measured on the scale.

The spheres A and C are given a similar charge by connecting them to a source of electricity. When A and C are charged, the charges on these repel each other with a certain force which depends on the values of the charges on A and C and also on the distance between them. You find that A is pushed a little downwards. A is brought back to its original position by moving a small wire loop (rider) weighing 10 mg on the arm NB of the rod The pointer P helps in knowing when this happens. The position R of the rider on the arm NB gives you an idea of of the force acting between A and C. The calculation is quite simple. The principle of the balance gives ;

Force F between A and C × distance AN = Weight of the rider × distance NR

Therefore, Force F between the two charges

$$F = \frac{\text{Weight of the rider} \times \text{distance NR}}{\text{Distance AN}}$$

In this experiment distance AN is 50 cm and weight of the rider is 10 mg ($9\,8 \times 10^{-5}$ newtons). These are kept fixed throughout the experiment. You can, therefore, know how F changes by observing changes in NR. In a typical experiment the following observations were obtained.

Voltage connected to A	Voltage connected to C	AC	NR
1000 volts	1000 volts	10 cm	11 4 cm
1000 volts	800 volts	10 cm	9.2 cm
1000 volts	600 volts	10 cm	6 8 cm
1000 volts	500 volts	10 cm	5.7 cm

Plot a graph between the charge on C (proportional to the voltage on C) against distance NR.

Voltage connected to A	Voltage connected to C	AC	NR
1000 volts	1000 volts	10 cm	11 4 cm
1000 volts	1000 volts	12 cm	7.4 cm
1000 volts	1000 volts	14 cm	5.8 cm
1000 volts	1000 volts	16 cm	4.5 cm
1000 volts	1000 volts	18 cm	3.5 cm
1000 volts	1000 volts	20 cm	2.8 cm

If you look carefully at these observations you find that when the charge on C is made half, the distance NR also becomes half of the original value. This clearly shows that the force F depends on the charge on the sphere. Secondly, when the distance AC is doubled, NR becomes one-fourth of the original distance. You can easily see that this means F has become four times smaller than the original force between A and C.

10 LIGHT

10.1 Sources of light

In a dark room you cannot see anything even though you keep your eyes open. As soon as you switch on a lamp or light a match-stick, objects in the room become visible. Thus, you can see only in the presence of light. On the other hand, you cannot see with your eyes closed even if the source of light is present. The eyes have the special property of sight. When someone loses this capacity he becomes blind. For vision you need a source of light as well as your eyes.

Question

It is said that a cat can see in the dark. Is this true ?

There are sources of light that are natural. The sun as you all know is one such source. There are other bright objects in the sky, like the stars. They are always there but the sun is so bright that they can not be seen during the day. Though light from the stars is very faint, nevertheless in a dark night if the sky is clear you can even make your way in starlight. Then there are artificial sources of light. The lamp, the electric bulb, the electric torch are examples of such artificial sources.

You will notice that there are luminous objects, which give out light by themselves. There are also non-luminous objects which do not produce any light. Most of the objects are non-luminous. The walls, the board, the bench, even human bodies are non-luminous. Then how do you see these non-luminons objects ? What happens is this. Light from a source falls on these objects, gets reflected and reaches your eyes to create the sensation of vision. Different

parts of the object reflect differently thus defining the shape of the object. You know that the moon is a non-luminous object and reflect the light from the sun. So are the planets.

Question

Do you know there are phases of the moon ?

Some non-luminous bodies can be made luminous. A piece of charcoal is ordinarily non-luminous but when it burns, it gains luminosity. Most objects if heated to sufficiently high temperature become luminous.

You have seen a coil of thin metal wire inside the bulb of an electric lamp or a torch bulb. This coil is known as filament of the bulb. When there is no electric current flowing, the wire is cold and non-luminous. As soon as you turn on the switch, electric current flows in the wire and it becomes very hot and luminous.

Question

When you turn the switch on, the circuit is closed and electric current flows through the coil. But why do you get light ? Is there any relation between light and electricity ?

There are various other sources of light. Fire flies and glow-worms emit light. There is a type of fish in the ocean that emits tiny specks of light. You must have noticed that the dial marks of certain types of time-pieces or watches glow in the dark.

Questions

(1) *Name other sources of light that have not been mentioned in the text.*

(2) *Can you name any kind of reflector you use everyday ?*

Activity

Which of the following objects are luminous? An electric stove when current passes through it ; the planet Venus ; a firefly ; a diamond ; a mirror ; a tree ; a piece of stainless steel ; a glowing torch ; a smouldering cigarette, a camera and a star.

Luminous	Non-luminous

10.2 Transparent and opaque objects

When you look through a window-pane you can see objects beyond. This is because light can pass through a glass pane. Substances through which light can pass are *transparent* bodies. Air, clear water, plastics are transparent bodies. There is another kind of glass called ground-glass through which light can pass partially. These are called *transluscent* bodies. Oil-paper, thin polythene sheets are examples of this type. When a large number of transparent glass plates (say, twenty or more) are stacked together, the combination appears like a transluscent body. If the thickness of water through which light passes is increased, light passes partially and appears dim. *Opaque* bodies do not allow light to pass at all through them.

Question

A thin layer of water is transparent. What happens if light passes through a great depth of water ?

Activity

Find out through which of the objects named below you are able to see the source of light. List these objects as opaque or transparent in the following table.

Glass ; water ; cellophane paper ; wood ; steel plate ; glycerine ; mustard oil ; paraffin ; a book and oil or greased paper.

Opaque	Transparent

Question

An astronaut moving far above the earth sees darkness all around him. Explain why ? (Hint : There is no atmosphere far away from the earth).

10.3 Colour of objects

Look at the objects around. You find that a tree is green, a rose is red, grass is green, your shirt is yellow, you have a blue note-book, and so on. Where do these colours come from ? What role does light play here ?

Take one sheet each of red, blue and green glass. Look at a sheet of white paper through the red glass. The paper appears red in colour. Look at the same paper through the green glass and then through the blue glass. The paper acquires that particular colour. What does the glass sheet really do ?

Activity

In four different beakers, prepare solutions of (1) NaCl, (2) NaOH, (3) Na_2CO_3, (4) $NaNO_3$. Take a thread of asbestos and soak it in solution of NaCl. Place it in a flame. Note down the colour of the flame. Now soak other asbestos threads in different solutions in turn and put them in the flame. What is the colour of the flame in each case ? What do you think the colour may be due to ?
Similarly, prepare solutions of three different salts of strontium and observe the colour of the flame in each case. What in your opinion is this colour due to ?

Look at the sheet of paper through the red glass. The paper appears red. Now place the blue plate over the red plate and look at the paper through the combination. If each of the plates adds something to the light coming from the paper, then both the colours should be seen. But the paper appears to be black. Thus the glass plates are doing something else to the light and not adding to it. A blue glass plate removes all the colours from the ordinary light except the blue, that is, light of all colours except blue are absorbed in the glass plate. In the same way a red glass plate removes all the colours from the ordinary light except the red one. In the experiment that you have just

done, the red plate allows only red light to pass through, but this red light is not allowed to pass through by the blue glass. The total result is that no light reaches the eye and the paper appears to be black.

Activity

(1) Take three glass plates of different colours—red, blue and green. Look through each of them towards the sunlight. *Do not look at the sun direct.* What do you observe ? Now look at the white sun light through a combination of red and blue glasses. Do you see any colour ? If you have a blue or red electric bulb, how do the objects appear in a room when the bulb is lighted ? Look at the red bulb through a blue glass. What do you find ? Next look at the same red bulb through a red glass. Do you find any change ?

(2) Take a steel wire and attach a piece of asbestos at one of its ends. Soak the asbestos in a solution of common salt and hold it in a spirit lamp flame. Do you get any coloured light ? If so, what is its colour ? Now look at the flame through a red glass or blue glass. What do you find in each case ?

Questions

Can you tell how (i) A green leaf would appear in red light ? (ii) A red rose in green and blue light ?

From activity (1) above, you find that red glass plate separates red light, the blue plate separates blue light and the green plate separates green light from

the white light. This means that white light contains the light of all these colours. Thus the colour of an object depends on the colour of light that reaches your eye. A leaf is green because it reflects only the green light and absorbs all other so that only green light reaches your eye. A rose is red because it only reflects red light and absorbs the rest.

10.4 Light travels in a straight line

To locate a source of light you always look towards the direction from which light reaches your eyes. You do this because you think that light travels in a straight line. You can verify this when sun light passes through the hole of a window in a dark room. If you want to check if all lamp posts are in a straight line, you use your line of vision as the yardstick. To fiix pins on a card board in a line you do the same thing because you believe that your line of vision is a straight line.

This experiment can be done easily. Take one rectangular wooden box of suitable size (figure 10.1).

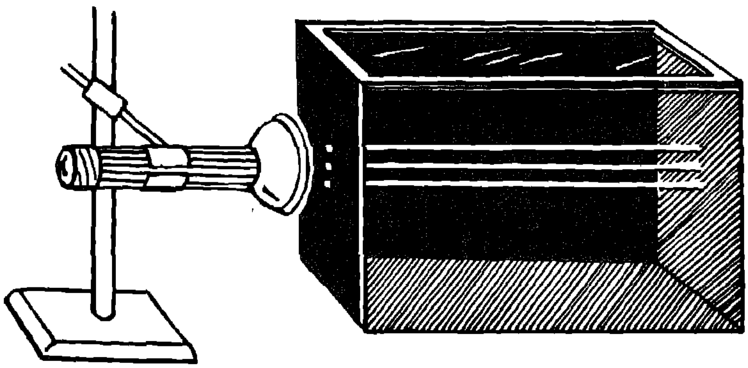


Fig. 10 1

Fit glass panes on the top of the box. One of the shorter sidefaces of the box is open. Cover this side with a sheet of black paper or carbon paper. Pour some chalk powder in the box. Make a few pin holes

on the black paper pasted on the side. Hold a lighted electric bulb or torch in front of the holes and look through the glass on top of the box. Observe that the light rays made visible by the tiny dust or powder particles show up as thin lines. Remember that the experiment should be made in a dark or semi-dark room.

Activity

Take three pieces of card board and place them vertically as shown in figure 10.2.

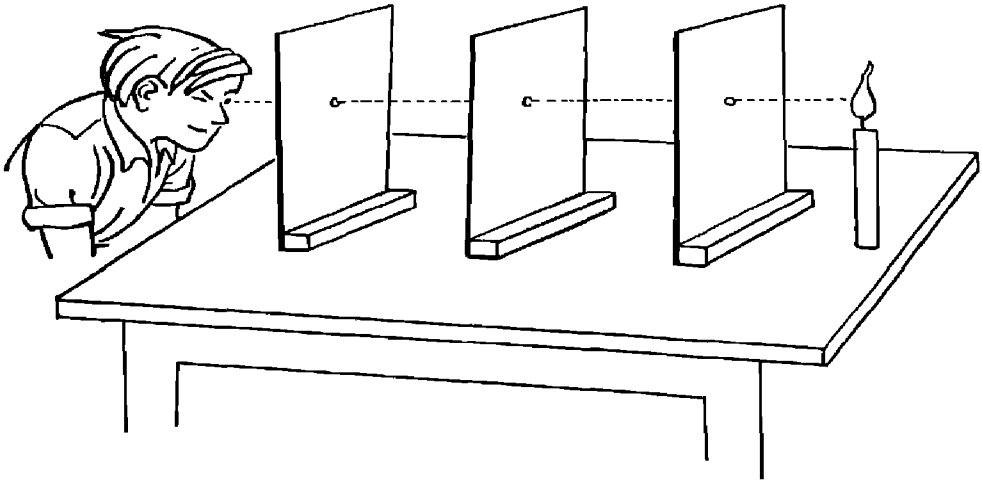


Fig 10 2

Each of the board is provided with a pin hole at the centre. Arrange the boards so that all the holes lie in the same straight line. Place one source of light behind one extreme board and keep your eye in front of the other extreme one. You will observe the ray of light passing through the holes. What happens if any one board is slightly displaced ? Arrange the boards so that the holes are again in the same position and light can be seen again from the other end. Hold

one glass block between two successive holes (figure 10.3). Can you see light again? Replace the glass block by a transparent glass bottle filled with water. What do you observe ?

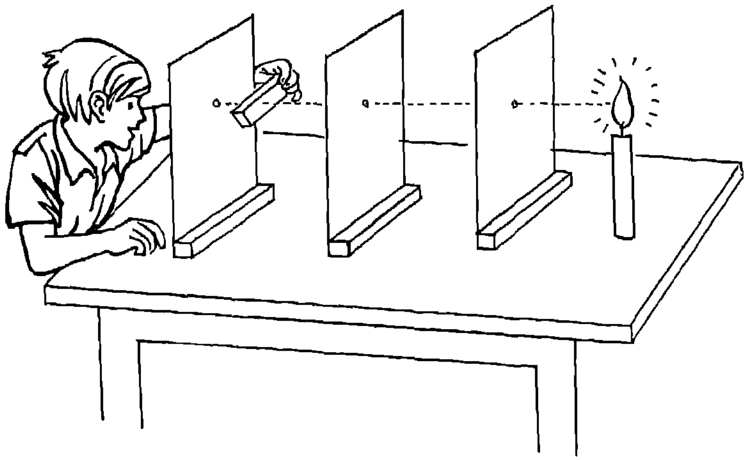


Fig. 10.3

Questions

(1) In the same substance (medium) does light travel in a staight line ?

(2) Four sticks stuck in a row, as in a wicket stump, stand in the field. Put your eye on level with the front one. Can you see the sticks behind ?

Do you think that you will get the same result if the sticks and you are under water ?

10.5 Shadow

All of you know that opaque objects cast shadows. When you walk in the sun the shadow cast by your body moves along with you. The size of your shadow depends on the time of the day. In the early morning or the late afternoon your shadow looks very long, while at noon the shadow is so small that it almost disappears. This is because at noon the sun is directly overhead. So you come to realise

that the size of a shadow cast by an object depends on the relative positions of the source of light, the object and the screen on which the shadow is cast.

Fig 10 4

You can set up an arrangement by yourself to observe how the shadow of an object changes. Arrange a source of light on a table. Place a screen as shown in figure 10.4. The screen can be made of a white sheet of paper or a card board. Now hold a pencil vertically between the light and the screen. You will notice a long vertical shadow of the pencil on the screen. If you hold the pencil horizontally across, the shadow will be long and horizontal If you tilt the pencil the shadow will be shorter. If you hold the pencil in such a way that the tip points towards the screen and the bottom face is turned towards the light source you will get a small circular shadow on

the screen. You can study the size of the shadow by moving the pencil towards the light source or away from it. You have to remember that all experiments in light should be performed in a semi-dark room, otherwise you would not see the shadow properly.

Question

When a weak source of light is replaced by a strong one, shadow of the same object appears darker. Why ?

To study the formation of shadows you can set up a source of light in the following manner. Take an ordinary torch and remove the reflector. Place it on a stand or hold it as shown in figure 10.5. Place

Fig. 10.5

the screen as shown in the same figure. You now take a ball and hold it between the source of light and the screen. You will find a circular shadow on the screen. If you move the ball towards the screen, the shadow becomes smaller and darker. If you move the ball towards the light source, the shadow becomes larger and fainter (figure 10.6). You

Fig 10 6

will notice that the shape of the shadow does not change if you turn the ball. Now replace the ball with a circular disc of the same diameter. If you hold the disc properly you will again find a circular shadow on the screen. Move the disc towards the screen and towards the light source in turn and record the nature of the shadow.

Question

Rotate the disc and find how the shape of the shadows changes.

Activity

Take any source of light (a candle, a lantern or a torch light), one screen (made from a sheet of paper or card board) and objects of different shapes. Put the objects one by one

between the source and the screen and examine the shapes of the shadows you get. Change the positions of the object, the screen and the source. What do you observe ?

10.6 Formation of shadow

While doing the experiments for producing shadows you must have noticed that the shape of shadows are very defined. Why is this so ? This is because of the property that light rays travel in straight line. In figure 10.7 L is the source of light,

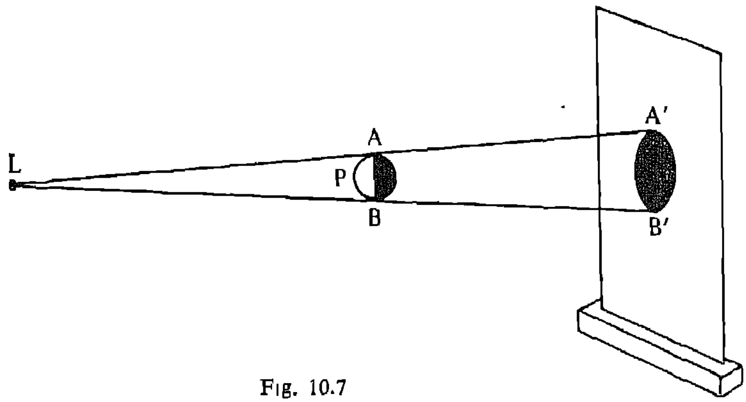


Fig. 10.7

P is the object and the shaded portion on the screen is the shadow. Let AB be the vertical diameter of the object. Draw a line joining L and A. Extend the line to reach the screen at A′, Draw another line joining L and B and extend it to reach the screen at B′. You can draw straight lines joining L to each point on the circumference around the diameter and extend these lines towards the screen. The outline made on the screen by the points where these lines reach will coincide with the outline of the shadow. If light could travel in a curved line you could find light rays in the shadow. You can find why the shape of shadow for the object does not change if the object is rotated in the same position.

Question

Replace the ball of figure 10.5 by a disc of the same diameter and construct geometrically the shapes of the shadows formed for 4 different positions of the disc.

10.7 Extended source smaller than the object

You must have noticed that in figure 10.7 the source of light L was taken as a point. But in practice any light source is much bigger than a point. The shapes of the shadows depend on the relative sizes of objects and the sources of light. Consider the case when the source of light is smaller than an object. Take a torch-bulb as a source of light and a steel ball larger in size than the torch bulb.

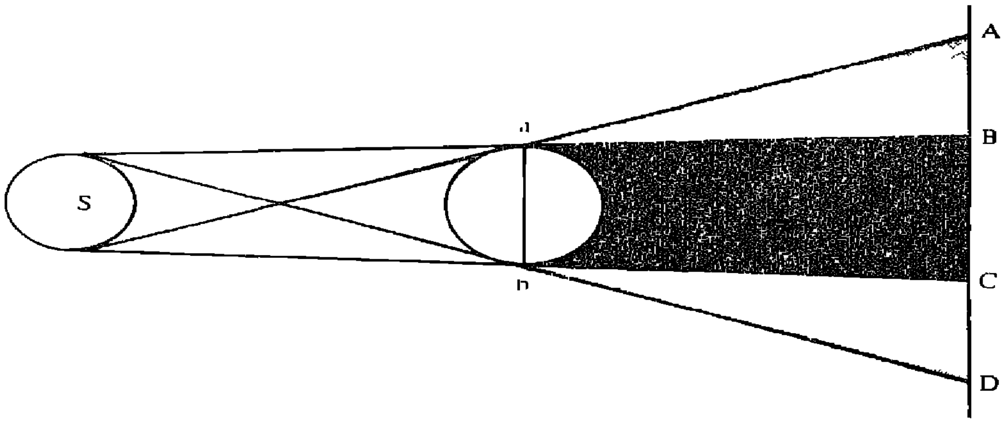


Fig 10.8

Place the steel ball between the source and the screen. Let S be the source and ab the object as shown in figure 10.8. Portion AB and CD will be partly dark but the portion BC will be completely dark. The dark portion of the shadow is called *umbra*. No part of the source can be seen by placing the eye at any point within this region. But a point lying within the region AB or CD will receive light

only from a certain part of the source. This area of the shadow is partially dark. It is called the *penumbra.* Shift the screen gradually away from the object. The area covered by both umbra and penumbra of the shadow will increase. You will observe a reverse effect when the screen is shifted towards the source. Draw a sketch on a piece of paper taking an extended source smaller than the object.

10.8 Extended source larger than the object

What happens when the source is too large than the object ? In figure 10.9 S represents the source

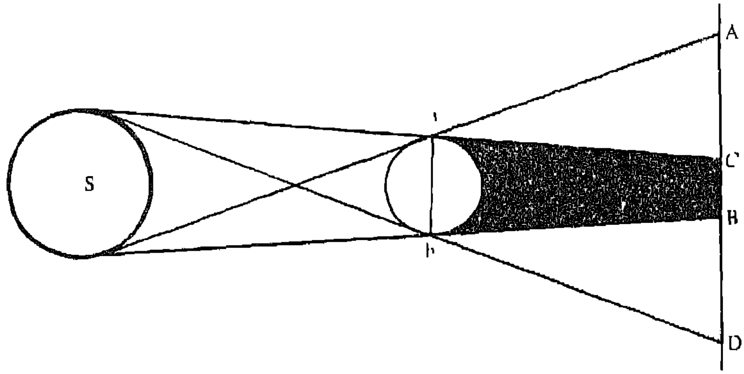


Fig 10.9

and ab the object when S is larger than ab. Draw the shadow ACBD as before with a scale. Regions AC and BD are penumbra of the shadow and BC is its umbra. Shift the screen gradually away from the source. The penumbra of the shadow will gradually increase in area but the umbra will gradually decrease and finally disappear.

Question

What happens to the umbra if the screen is shifted further from the source ?

Activity

Place a card board with a small hole in front of the source of light. Place a ball between the source and the screen. Light comes through the hole which is the source here. The area of the hole on the cardboard is smaller in size than the object. You will get a circular shadow on the screen surrounded by a faint circular patch of light. The completely dark portion is called umbra and the partly dark portion is called the penumbra of the shadow. Shift the screen away from the object and notice the change. Replace the cardboard by another with a hole larger in size than the object Place the object between the source and the screen. What do you observe now ?

Hold a piece of thread very close to the ground when the sun is overhead and a thin dark line of shadow forms. Move the thread up and up away from the ground and notice what happens to the shadow.

Question

Why do eclipses occur ?

10.9 Pin-hole camera

Do you know how a pin-hole camera works ? You can use any rectangular box to make it. Even a shoe box would do. Replace one end of the box with a sheet of paper which will be the screen to receive the image and pierce a pin-hole at the other end. Now watch what happens from figure 10.10. P is the pin hole and SS' is the cross section of the screen and OO' is an object, say a lighted candle. Place the camera so that the line joining the centre

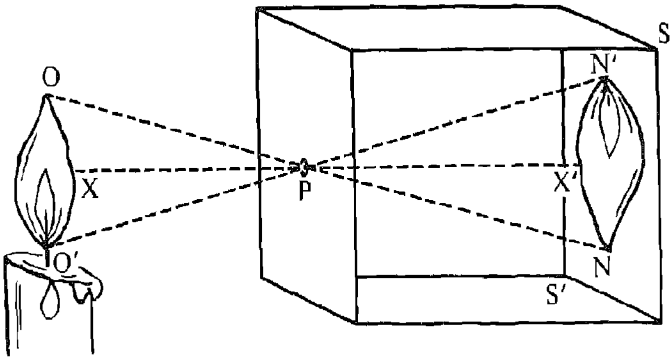


Fig. 10 10

of the screen and the pin hole passes through the centre of the object OO'. A ray of light starting from O will proceed through the pin hole along OP and reach the screen at N. Similarly a ray of light from the point O' proceed along the straight line O'P and reach the screen at N'. A ray from X passes through P and reaches the screen at X'. A ray from any point between X and O will reach the screen between X' and N. Similarly a ray from any point between X and O' will reach the screen between X' and N'. Thus you find that NN' would be an upside down image of the candle. This argument holds only because light rays travel in straight lines.

Activity

Make your own pin hole camera. Measure the height of the object OO' and mark on the screen the height of the image NN'. Find out the ratio of $\frac{NN'}{OO'}$. This ratio is known as the magnification factor of the camera. Change the distance between the pin hole P and the object. Record the ratio $\frac{NN'}{OO}$ for each position of the object. What do you find ?

Measure the distance PX′, i.e the length of the box. Now record your observations in the following chart.

$\frac{PX'}{PX}$	$\frac{NN'}{OO'}$
(1)	
(2)	
(3)	
(4)	
(5)	
(6)	

When will NN′ be equal to OO′ ? Find out what happens if you go on making the pin hole bigger.

10.10 Reflection

When you look at a mirror you always find your image and the images of everything around you. How does it happen, you must have wondered. This is possible because light rays are reflected from a polished surface much in the same way as a tennis ball bounces back after being dropped. A ray of light from any point on your face or from any object around you travels towards the mirror then gets reflected to reach your eye. A number of such rays after reflection produces the image in your eyes. You see the image in the mirror. If you remember the kind of image you saw in a pin hole camera you will notice a difference. The image in the camera is a *real image* which forms on a screen. But when you look in a mirror, you see the image but you cannot

hold that on a screen. This is not a real image but a *virtual image*.

Sometimes you see patches of light dancing on a wall beside a pond or beside any other surface of water gleaming in the sun The rays of sun light are reflected from the water and form an image on the wall. This is an example of real image.

Question

Why does the patch of light dance ?

Rays of light get reflected from any surface, but for getting a sharply defined image the surface has to be smooth, flat and polished. You must have noticed that a highly polished metal surface behaves very much like a mirror. The mirrors that you normally use are made by silvering the back surface of thin smooth transparent glass plates. A mirror made of a flat glass plate is called a *plane mirror*.

Take a smooth glass plate and tilt it slightly so that light rays fall on it obliquely. You will notice that light rays are reflected in a definite direction. Replace it by a ground glass Now light will not be reflected in any definite direction but will scatter in all possible directions. This is called diffused or irregular reflection. You will observe the same effect with a piece of paper. Rough surfaces always show diffused reflection. Most of the objects are rough and become visible by irregular reflection. A mirror strip reflects irregularly when its surface is covered with dust.

Activity

(1) Take a mirror and hold it vertically on a cardboard kept on a table. Place a protractor horizontally in such a way that its base coincides with the base of the mirror as shown in figure 10.11.

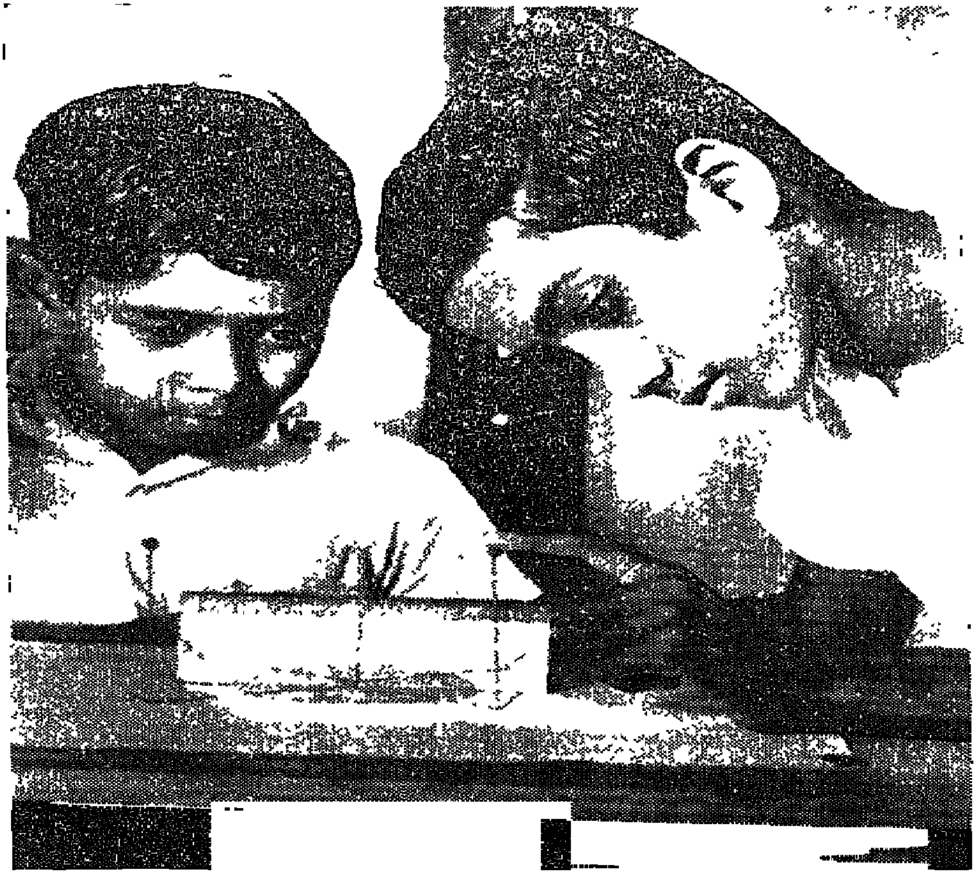


Fig. 10.11

Fix a pin near the centre of this mirror. Tie two threads to this pin and attach a pin to each of the free ends. With the protractor edge against the mirror, stretch one of the threads and stick its pin at any position on the cardboard. Call it pin No. 1. With one eye closed see for the reflection of the pin over the central pin. Stretch the thread of the second pin (call it pin No 2) so that it is in line with reflection of pin No. 1. Fix pin No. 2 at that position. Find the angle

from the mirror to each thread. What do you find ?

(2) Hold the mirror strip vertically with a protractor at its base as before. Now take two straws and hold one of them at an angle to the protractor and directed towards the mirror as shown in figure 10.12.

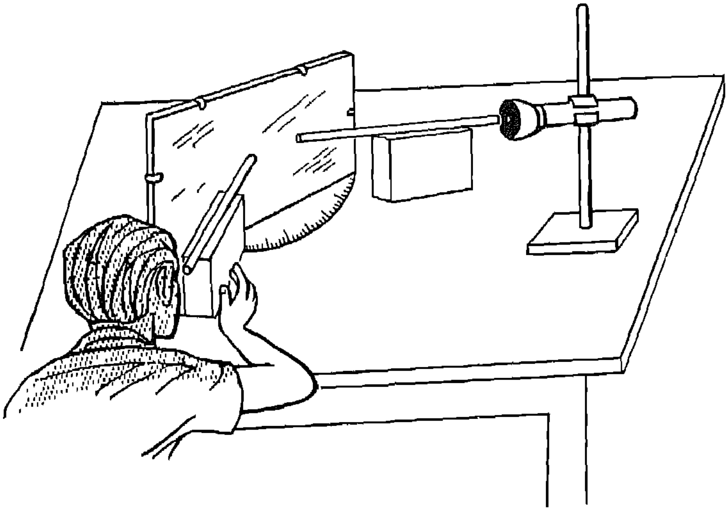


Fig 10.12

Read this angle on the protractor. Take a torch or flashlight, cover its face with a black paper and cut a small hole in this paper near the centre. Allow the light to pass through the straw and on to the mirror. What do you find ? Now look at the light reflected by the mirror through another straw. Adjust the straw till you are able to see the reflected light. Fix the position of the straw and note down the angle it makes on the protractor. Are the angles same for each of the straws ? Change the direction of the first straw. Do you have to change

the inclination of the second straw ? Verify for various settings of the straw, that when you see the light reflected through the second straw, the two straws are equally inclined to the mirror.

You have seen from the above experiments that light is reflected from a mirror in a particular direction. The angle between a mirror and the path of light from an object to the mirror is equal to the angle between the mirror and the path of the light reflected from the mirror.

Now see how an image is formed by a mirror.

Activity

Take a sheet of white paper and fix it on the table. Draw a straight line AB on the paper near its middle. Take a mirror and hold it vertically on the line AB. Fix a pin at the position P in front of the mirror as shown in figure 10.13.

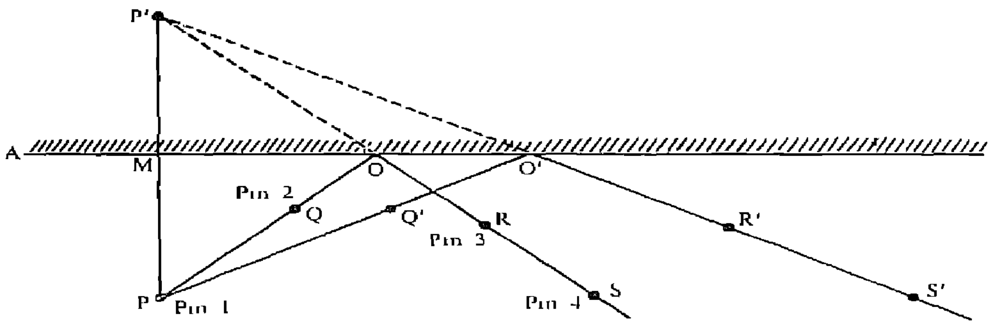
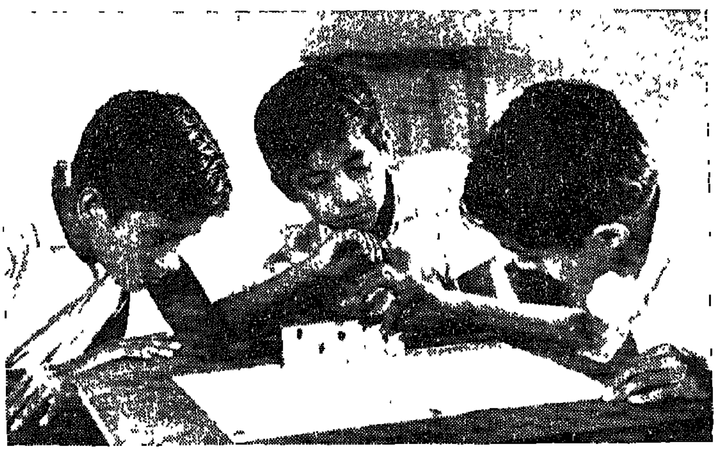


Fig. 10.13

Call it pin No. 1. Find out the position of the image of this pin in the mirror. Take another pin, call it No. 2 and fix it at the position Q. Look at the mirror from the other side to see the images of the pin No.1

and No. 2. Fix two other pins, No. 3 and No 4 at points R and S in the line of sight of the images of pins No. 1 and 2 so that feet of all the four pins appear to be in a straight line. If you move your eyes now, all the four pins will appear to move together with the movement of your eyes. Remove the pins one by one. Indicate the positions of the pins by means of small circles Now put pin No. 1 again at position P, but fix pin No. 2 at some another position, say Q' and repeat the experiment. Fix pin No. 3 and No. 4 at positions R' and S' so that feet of the pins 3 and 4 and those of the images of pin Nos. 1 and 2 appear to be in a straight line. Remove the mirror. Join PQ, RS, PQ' & R'S' and extend the lines PQ, RS, PQ' and R'S' to meet the line AB at O and O'. Now produce the lines RS and R'S' on the backside of AB. What do you find ? You will find that two lines meet a point. Call this point P'. Joint P and P'.



PP′ meets AB at M. Is the distance PM equal to the distance P′M ? P′ is the image of P and lies as far behind the plane mirror as the object P is in front of it. In other words, the distance of the object in front of the mirror is equal to the distance of the image behind the mirror. This image cannot be received on a screen. If the point P is shifted to some other position, P′ will also be shifted accordingly. Repeat this for various positions of the pin P. Enter your observations in a table as shown below :

Distance of P from the mirror	Distance of P′ from the mirror	Angle PMP′

10.11 Lateral Inversion

Look at yourself in a mirror. Is your image exactly like the view that the other people get of you ? Raise your left hand. Which hand appears to be raised in the image ? If you have a mark on your right cheek, where does it appear in the image ? Place a scale in front of the mirror. How do the markings appear in the image ? You will find that your left hand side is not so to your image. 'Left' and 'Right' sides appear to have inter-changed their positions. This type of interchange is called *lateral inversion*.

Activity

(1) Write the letter 'b' in a bold type on a white paper and hold it before the plane

mirror. What do you find? Does the letter in mirror look like b or d?

(2) Write the word AHIMOTUVWX on a paper and hold it before the mirror. What do you see in the mirror?

Stand before a mirror. Move towards it. Does the image move towards you or away from you? If you move away from the mirror, does your image move at the same rate as you do?

Activity

Hold the mirror in your hand and move it towards or away from your face. What do you find? Now instead of moving the mirror, fix it on the wall and move towards or away from it. What do you observe? Some statements are given below. Mark the correct ones.

(a) When the object approaches the mirror, the image also approches/recedes from the mirror.

(b) When the object recedes from the mirror, the image also recedes from/approaches the mirror.

(c) When the mirror approaches the object, the image also approches/recedes from the object.

(d) When the mirror recedes from the object, the image also recedes from/approches the object.

10.12 Multiple Reflection

Fix two mirror strips vertically parallel to each other and about 20 cm apart. Place a small lighted candle between the mirrors. Look at images through one mirror and then through the other mirror,

What do you find ? You will find many candles. Do you see same number of lighted candles in both the mirrors. Can you count the number of candles in each of the mirrors ?

Activity

Take two mirrors and place them vertically. Place a toy in between the two mirrors. Count the number of images (figure 10.14.)

Fig 10.14

Now place a protractor below the two mirrors. Adjust one mirror along the base and another at 90° line of the protractor. Put the toy again and what do you find ? How many images do you see ? Decrease the angle between the mirrors to, say 60°, 45°, 30° and count the number of images in each case. Do you get the same number of images ?

If the mirrors are inclined, the number of reflections is limited depending upon the inclination of the two mirrors. This can further be demonstrated by making a very beautiful toy known as *'Kaleidoscope'*.

This toy utilizes multiple reflections to produce beautiful patterns. It is a great fun to make one such toy. See how this can be done.

10.13 Kaleidoscope

Take three rectangular strips of plane mirrors and arrange them to form a triangle. Place these mirrors in a cylindrical cardboard tube fitted tightly. At one end of the tube, place small pieces of coloured bangles between two glass plates which fit into the tube. Place another glass plate at the other end. Cover this end with a black paper having a hole at its centre. Look through this end and rotate the tube. You will find very beautiful coloured patterns.

10.14 Periscope

Take two mirror strips and fix them in a tube at an angle of 45° to the axis of the tube as shown in figure 10.15. There is an opening at the top and one at the bottom of the tube. Light coming from the upper opening falls on the mirror No. 1. This is reflected by this mirror which then falls on mirror No. 2. It is again reflected by this mirror and your eyes placed near the opening at the bottom see the object. An instrument constructed on this principle is called a *periscope*.

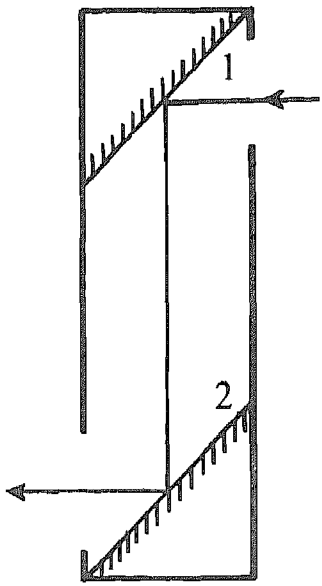


Fig. 10.15

Question

Can you think of any use of this instrument ?

10.15 Bending of light rays

You have noticed above that the shadow or the path of light have a sharp boundary. This shows that light travels in a straight line and does not bend round edges. But this is not wholly true. The object that you used in between the path of light are sufficiently large. If, however, you place very tiny objects like a

thin wire, you will get an image of an entirely different pattern. See if this is so.

Hold two fingers in front of your eye in such a way (figure 10.16) that you look at light through the very fine slit between them when they are not pressed tightly together. Look at a source of light such as a neon tube or a fluorescent lamp. What do you find ?

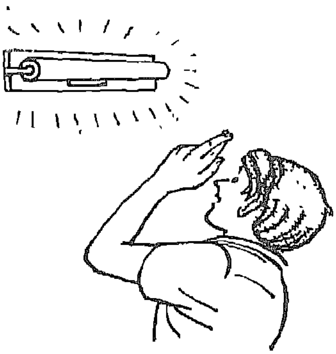


Fig. 10.16

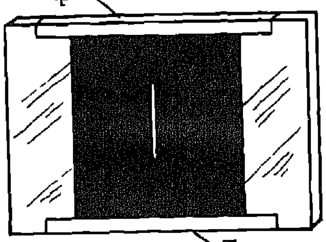


Fig 10 17

Activity

Take a clean glass plate and paste a black paper on it as in figure 10.17. Using a scale cut a narrow line on this black paper with the help of a razor blade. Now look at a source of light, say a neon lamp through this line. What do you observe ? Do you see only one bright line or number of lines ? Now make the slit broader and see what happens.

You thus find that very thin slits placed in the path of light gives alternate dark and bright pattern. This means that the light must have deviated a bit from its path to give the bright patch. There is a slight bending of the path of light around edges. You will learn more about it as you learn more of Physics.

Dear Reader

We have great pleasure in sending you a copy of an experimental edition of the Physics text book for the age group 11^+ (class VI).

With the explosion of knowledge connected with science and technology, it has been realised all over the world that the teaching of Physics at elementary levels should be based more on an experimental approach which, it is hoped, will provide a sense of inquiry in the young minds For the first time in our country, a large section of physicists in the universities are collaborating in the programme of improvement in Science education in schools. This book is a result of this collaboration. The authors are well aware of the shortcomings in this book which have resulted out of the short time at their disposal in getting out this experimental edition.

The volume is being sent to you with a definite purpose. It is needless to say that your constructive suggestions for its improvement will go a long way in revising this experimental edition and bringing out the first set of books for Physics for Indian schools. With this objective we enclose a questionnaire which you may kindly fill after studying the book and return it to us.

Yours sincerely
V. G. BHIDE

National Physical Laboratory
New Delhi 12.

COMMENTS ON THE NCERT PHYSICS STUDENTS' TEXT-2

Name, designation and address
of person making comments.

Date

(If the space provided against the question is not sufficient please attach additional sheet. In your comments, please indicate wherever p(
a comment is primarily based).

Chapter	I	II	III	IV	V	VI	VII
1. Is the matter presented in the chapter comprehensible to the students of the age group to which it is intended? If not, what are the portions which you consider as above the standard? How should these be modified to suit the students' comprehension? Would you suggest any addition to the text?							
2. Do you think that the development of concepts are natural and continuous? Are there any places where it appears to be abrupt? Suggest how these could be improved							
3 Do you think that the approach to the topic is such as would induce curiosity and a sense of inquiry in the mind of the student? If not, what modifications should be made to achieve this?							